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A STUDY OF HAZARDOUS WASTE MATERIALS, HAZARDOUS EFFECTS AND DISPOSAL METHODS

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Volume I of this three-volume inventory of hazardous wastes in the United States, describes the purpose, scope, approach, and principal findings of the study. An identification of hazardous materials is given that describes the occurrence of hazardous wastes, its analytical problems, and a list of hazardous compounds and its uses. Hazardous wastes are quantified. A development of a rating system of hazardous materials is included in a survey of hazardous effects. Treatment and disposal methods are surveyed and inventoried. Conclusions and recommendations are presented as are listings of principal literature references for each chapter and a full bibliography at the end.

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A STUDY OF HAZARDOUS WASTE MATERIALS, HAZARDOUS EFFECTS AND DISPOSAL METHODS
Volume 1

By

Booz Allen Applied Research, Inc.
Bethesda, Maryland

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Cincinnati, Ohio 45268

Prepared for
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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and

- a search for ways to prevent contamination and to recycle valuable resources.

The study reported here in three volumes was designed to present background information on hazardous materials for the report to Congress on "National Disposal Study Sites." All persons involved in disposing of or concerned with hazardous wastes will find these volumes of interest.

A. W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

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I. SUMMARY

Presented in this Chapter are summary discussions of the background to the study, its objectives, the approach followed in conducting the study, and the principal study findings and recommendations.

1. PURPOSE AND SCOPE OF THE STUDY

This study was originated as the first in a series that would assist the Environmental Protection Agency (EPA) in complying with Section 212 of the Resource Recovery Act of 1970, which requires that a "National Disposal Sites Study" be completed and reported to the Congress within two years after enactment of the Act. For the sake of clarity, the controlling portion of the Act is reproduced below.

> National Disposal Sites Study
>
> Sec. 212. The Secretary shall submit to the Congress no latter than two years after the date of enactment of the Resource Recovery Act of 1970, a comprehensive report and plan for the creation of a system of national disposal sites for the storage and disposal of hazardous wastes, including radioactive, toxic chemical, biological, and other wastes which may endanger public health or welfare. Such report shall include: (1) a list of materials which should be subject to disposal in any such site; (2) current methods of disposal of such materials; (3) recommended methods of reduction, neutralization, recovery, or disposal of such materials; (4) an inventory of possible sites including existing land or water disposal sites operated or licensed by Federal agencies; (5) an estimate of the cost of developing and maintaining sites including consideration of means for distributing the short- and long-term costs of operating such sites among the users thereof; and (6) such other information as may be appropriate.

This study was structured to address points (1) and (2) in Section 212 (previous page), and a Scope of Work to be performed was developed and published by the EPA.

The study was essentially designed by the EPA as a comprehensive literature search for the information and data of interest. Thus, the extent and depth of the results are directly dependent upon the availability of the desired information and data in the literature.

The study had four principal objectives:

- Provide a list of hazardous materials which should be subject to special disposal techniques
- Document the harmful effects that we know now and provide a mechanism for revising this information as new data becomes available
- Develop a rating system for delineating the degree of hazard
- Provide an inventory of current disposal practices and an evaluation of these practices.

The study ends with the conclusion of the fourth objective above. This report provides information which satisfies those objectives, subject to the limitations of information available in the literature, and provides direct inputs to the second study in the hazardous wastes program series.

It is recognized that the scope of this first study is very broad, perhaps too broad, but included no preconceptions as to identity of hazardous materials, the form in which they might be encountered, the potential for hazardous effects, or the nature and extent of present treatment and disposal methods.

2. APPROACH TO THE STUDY

The overall approach to conduct of the study consisted of a general study design and a detailed approach followed within the framework of that design. These two features are described below.

(1) Study Design

The general study design established the overall guidelines for conduct of the study, and comprised three principal elements:

- Information available from literature sources
- Information screening and categorization by Standard Industrial Classifications
- Exclusion of municipal wastes from detailed consideration.

Since no defined subject-matter preconceptions were provided by the EPA, it was necessary to establish guidelines for the literature search in order to identify the potentially useful literature references in the shortest possible time. Therefore, as references were identified, they were initially screened for possible value to the study, the categorized according to Standard Industrial Classification (SIC) and the associated identifier codes. The SIC groups were selected to reflect the major manufacturers and users of potentially hazardous materials, and to aid in geographic location of those materials. The latter is especially important with respect to the occurrence of hazardous materials as—or in—wastes, since the principal thrust of the study was to identify materials whose associated hazards are such that special waste management techniques might be required during disposal operations. Within the context of categorization by industry groups, the federal government agencies most involved with hazardous materials, the Department of Defense and the Atomic Energy Commission, were also treated as industry groups.

The remaining principal guideline in the study design was the exclusion of municipal wastes from detailed consideration. This was done because domestic and municipal wastes represent so varied a mixture of materials of all types that the study resources could easily have been consumed in investigating that area alone (i.e., this area was considered too broad for this contract). Limited consideration had to be given to these wastes, however, to take into account the practice in some areas of industrial wastes being discharged in municipal waste systems.

(2) Detailed Approach

The detailed approach to conduct of the study included the following principal elements:

- Identification of literature sources
- Identification of industry and government groups for information categorization
- Collection of information
    - Literature
    - Industry associations
    - Government agencies
    - Plant visits
- Data recording
- Rating systems.

Identification of Literature Sources. To assure that comprehensive coverage would be obtained in identifying potentially valuable literature sources of information, a review was made of the subject-matter fields of interest of the leading technical abstract services. As a result of this review, and in view of the many topical duplications that exist among these services, the following abstract journals were decided upon as the principal literature reference sources:

- Applied Science and Technology Index (Wilson Co.; New York, New York)
- British Technology Index (Library Association; London, England)
- Chemical Abstracts (American Chemical Society; Columbus, Ohio)
- Engineering Index (Engineering Index, Inc.; New York, New York)
- U.S. Government Research and Development Reports (U.S. Department of Commerce; Washington, D.C.)

These abstract journals were searched beginning with calendar year 1960 and moving up through the 1971 mid-year issues. No limitations were placed on subjects; rather, the search included all subject matter that might, in any way, be considered applicable to the purposes of the study.

This search resulted in the identification of some 4,000 publications (books, papers, articles), and the collection and review of the abstracts of each. The abstracts were subjected to an initial screening for applicability and content, which reduced the number of publications to be reviewed to about 2,000. The 2,000 publications were reviewed by the study team members, and final decisions were made as to whether the included information was worthwhile to the study. As a result of these reviews, the number of publications from the above sources deemed to contain information useful to the study, and therefore worthy of detailed study, was reduced to approximately 700. This group was later supplemented by publications from other sources to bring the study bibliography to about 800 publications.

Identifications of Industry and Government Groups for Information Categorization. The subject matter of the publications identified and collected through the literature search covers a wide variety of interest in materials and their sources, production processes, uses, environmental pollution, and disposal methods. It became apparent, however, that certain industries constituted the principal manufacturers and users of potentially hazardous materials, and experienced many environmental pollution problems.

For this reason, it was determined that the collected information could be handled most systematically if it were categorized according to industry groups. To complement the industry group identification indicated by the literature, reference was made to a listing entitled "Major Sources of Pollution", which was developed during 1967-1968 by the Federal Water Pollution Control Administration (see Table II-1, page II-6). The list covers the top 50 pollution sources (from the viewpoint of water use), and includes natural and nonindustrial sources as well as the industrial sources. In addition, the list presents a priority ranking indicating the relative severity of the pollution problems created by the sources named.

The pollution sources named in the list referenced above, were compared to the industry group identities indicated through the literature search, and a list of industry groups was developed for use in categorizing the study information (see page II-9). A distinct added advantage of this approach is its use in geographically locating the major hazardous material use-points, and consequently the location of potentially hazardous wastes. These industry groups are identified by their Standard Industrial Classification codes. The industry group list has also been supplemented by identities of federal government agencies most concerned with the manufacture and use of potentially hazardous materials. The appendices to this report (Volumes II and III) provide descriptions of the listed groups, products, production processes, wastes, and waste treatment and disposal methods.

Collection of Information. The information utilized in this study was collected from:

- Literature sources
- Associations (industry and professional)
- Government agencies
- Plant visits.

As stated previously, the essential information source was the comprehensive literature search, and the latter three sources were used to supplement the literature where possible.

Contacts were made with 20 industry associations (see page II-15), in an effort to collect up-to-date information on the hazardous materials production, handling, and disposal problems of their member organizations.

Government agencies contacted were those deemed most likely to be concerned with potentially hazardous materials. These were:

- Atomic Energy Commission
- Department of Agriculture
- Department of Commerce
- Department of Defense (and the military agencies)
- National Aeronautics and Space Administration.

A limited number of plant visits were made for the purpose of confirming or verifying information obtained from the literature. Such visits included industrial plants, hospitals, and private disposal companies, but were limited in number since the project did not envision a major survey effort.

Data Recording. As the hazardous materials were identified, pertinent data for each describing material characteristics, toxicity values, production quantities and locations, and disposal procedures were collected, formatted, and reduced to punched cards. At the conclusion of the study, all punched-card data was converted to a computer print-out which was submitted separately from the report.

Rating Systems. In accordance with the study objectives rating systems were developed which indicate relative severity of effects of the hazardous materials, and for the associated waste treatment and disposal methods currently in use. The rating system for hazardous effects includes effects on man and on the environment, and takes into account, as weighting factors, the production quantities and the scope of distribution of the materials in the economy. A rating system for treatment and disposal methods was established which is based on the relative efficiencies of the methods used in nullifying the strengths of certain wastes to levels acceptable in sewage treatment plants.

3. PRINCIPAL FINDINGS OF THE STUDY

The principal findings resulting from this study are discussed below under appropriate topical headings.

(1) Adequacy of the Literature

The literature search which formed the basis of the study was very broad, covered over ten years' span of publications, and initially included some 4,000 documents. It was found, however, that the literature is insufficiently definitive to permit full achievement of the objectives of the study, because the literature:

- Provides no common definition of the term hazardous material;
- Provides little quantification of specific wastes or waste streams;
- Contains little information on chronic effects of materials on man or the environment, and is inconclusive with respect to acute effects;
- Indicates that, as a rule, the nature and extent of technology applications in waste treatment and disposal are based on economics rather than on pollution control considerations;
- Is very repetitious in that single sources of information and statistical data are used repeatedly by many different interests;
- Provides considerable research and development engineering information for materials and for waste treatment and disposal processes, but little information on practical applications; and
- Indicates that proprietary interests preclude disclosure of much information that would be pertinent.

Each of these findings is briefly discussed below.

Many writers have struggled with the term hazardous material, in this country and abroad, but the definition problem has yet to be resolved. In fact, the literature also demonstrates that the same problem exists regarding the term toxic, which is usually regarded as the more specific term. There is, of course, general agreement with respect to labeling certain materials as hazardous (e.g., radioactives, known deadly poisons, explosives), but the list of materials for which such agreement exists is short.

The matter of quantification of specific materials in wastes is one which has received very little attention. The literature indicates that, at any one installation, wastes from many processes are routinely collected into single flow paths, or streams, for treatment and disposal. These mixed waste streams may contain several materials that could be classified as hazardous materials, but the waste streams are not analyzed for constituency or to determine the results of possible reactions after mixing. Rather, if analyses are made, the parameters determined are those commonly measured in sewage disposal operations (e.g., BOD, COD, TDS, TSS, and perhaps the heavy metals). The result is that neither the quantity of any one material going into the waste streams, nor the actual make-up of the mixtures, are known. The principal assistance provided by the literature with respect to quantification of wastes is that, in some cases, waste generation factors are given (e.g., factors indicating the amounts of total process waste produced per pound or per ton of product), but on a generalized basis rather than for wastes from specific plants in specific plants in specific locations.

The literature utilized in this study as hazardous effects information sources included many well-known references on human toxicity of materials, similar works with respect to animals, research reports, and listings such as that published by the Occupational Safety and Health Administration. The greatest information gap was found to exist in the area of chronic (long-term) effects. It appears that very little testing has been done, even for determining the long-term effects of materials known to have serious acute (short-term) effects. Further, for materials known to have minor acute effects, or materials that have demonstrated no acute effects, research into possible long-term effects is nonexistent. The few exceptions involve materials which have little or no short-term effects, but which are known to be accumulated by the human or animal body.

In the area of acute effects, especially with regard to human toxicity, the literature indicates much lack of agreement among medical researchers. The essential reasons for this situation are the wide variations that have been observed in effects of the same materials on different people, and the many problems inherent in translating laboratory animal test results into human toxicity values.

With respect to waste treatment and disposal methods, the literature contains considerable information on research and development of specific methods for specific materials, but little definitive information concerning practical applications of the resultant technology. The bulk of the methods currently in use appear to be those applied to treatment of mixed wastes for the general parameters noted above (i.e., parameters of interest in general sewage treatment, with little attention given to specific materials). Business economics determine the nature and extent of waste treatment technology applications and the choice of final disposal methods, except in cases where the wastes are known to be hazardous. If wastes contain materials whose value makes recycling and reuse economically attractive, the treatment methods (aimed at extraction of the valuable materials) are likely to become sophisticated, and generally beneficial in terms of "detoxification" of the ultimate waste discharge. In situations where the producer feels that the wastes contain nothing worth recovering, the economic choice becomes one of selecting the least costly disposal method. Characteristically, this choice quickly reduces to one of "dumping" the wasteload—to water if a stream or body is convenient, or to landfill. For solid wastes or heavy, high viscosity liquids (e.g., sludges, filter residues, paints, grease), landfills have long been the preponderant disposal choice, but with little regard for any consideration except getting rid of the wastes. Finally, the literature indicates that in many industrial sectors, waste characteristics and treatment methods employed are not revealed since such information would reveal information about proprietary production processes.

Study of the literature also demonstrated that, in many areas, a limited number of information and statistical data sources are used repeatedly in different publications and that, in the end, sources of original data are relatively few in number. In some instances, for example, study of publications obtained from industry associations showed that the included data were identical to those given by the Census of Manufactures and extracted from the latter. In other cases, it was found that technical data furnished by certain technical groups (e.g., the Manufacturing Chemists Association), was used by many authors.

(2) Information Sources Other Than Open Literature

Beyond the open literature, potential information sources in the study were trade and technical associations, government agencies, and individual plants.

The industry association contacts met with varying degrees of success in terms of information collection. While some have published reports, etc., which are available in the literature, many of these groups have only recently initiated work with respect to environmental pollution and waste disposal problems of their memberships, or have undertaken no specific technical work at all. Naturally, the more technically oriented of these groups were able to provide some assistance. As a whole, however, while all of these organizations are interested in and concerned about pollution control problems, they were able to provide only limited assistance.

The government agencies most directly concerned with hazardous materials are the Department of Defense and the Atomic Energy Commission. Each of these was able to provide considerable information, especially the Atomic Energy Commission, since the radioactive materials are under continuous regulatory control throughout their life cycles. The Department of Defense agencies also have the opportunity for close control but, with the exception of munitions, have only recently initiated widespread control measures with respect to environmental pollution. These agencies find themselves in a situation similar to industry, in that the many installations utilize a wide range of potentially hazardous materials and produce potentially hazardous wastes, yet lack definitive background information and data that would be helpful in understanding pollution problems and alleviating waste treatment and disposal problems.

Visits to industrial plants generally confirmed the lessons learned from the literature, and are:

- Industry has not made detailed, comprehensive analyses of its wastes, and cannot provide quantitative data, especially with respect to specific materials contained in wastes.
- Waste treatment in industry is generally limited to treatment of mixed wastes for a limited number of parameters (e.g., oxygen demands, solids content, acidity, alkalinity) rather than for specific materials content.
- The nature and extent of waste treatment and disposal methods is based on economic factors rather than on pollution control considerations.
- By far the dominant disposal method is discharging to water with landfilling a close second.
- Many production processes which emit wastes which are of interest in environmental quality control are considered proprietary processes, for competitive reasons, and industry refuses to disclose process information that would aid in understanding the wastes generated.
- In many quarters, industry feels it is being unfairly attacked with respect to pollution and therfore is unwilling to discuss waste emissions, even where no proprietary processes are involved, for fear of stringent controls being imposed.
- A number of industrial firms across the country have been cited by the EPA, and by state and local environmental protection agencies, for violation of air and water quality regulations and, in some instances, these citations have resulted in litigation. In such an atmosphere, industrial firms in general have become extremely wary of disclosing any information about their wastes.

The findings on the previous page were also borne out through the contacts with industry associations. A final important consideration with respect to industry is that of attitudes and concepts regarding just what constitutes a hazardous material. Many individuals involved in daily handling of acids, caustics, pesticides, etc., especially as wastes, simply do not consider these as hazardous materials. The lack of agreement on definition of hazardous materials does nothing to help this situation.

(3) Definition of Hazardous Materials

Initial guidance with respect to definition of hazardous materials was provided by the EPA, as follows:

> "For the purpose of this study, hazardous wastes materials are defined as those materials or combination of materials which require special management techniques because of their acute and/or chronic effects on the health or welfare of the public (or those individuals who handle them) when they are disposed of by waste management processes (e.g., storage, transport, incineration, sanitary landfilling, composting, dumping, industrial waste treatment)."

While the definition provided was imprecise, it remains a good general definition. Precision in definition must address the question, "Hazardous to what and in what way?". If hazards to humans are under consideration, for example, a distinction needs to be made as to whether toxicity (which implies personal medical problems) is being considered, or whether safety hazards (e.g., explosion) are the subject. Both may be injurious, even lethal, but the nature of the hazards is distinctly different. Similar considerations would apply to the definition of materials hazardous to animal and plant life.

For purposes of the analyses and hazardous effects ratings in this study, materials (and to some extent, waste streams) have been defined as hazardous if they have the known inherent ability to produce:

- Toxic effects on mammalian species (whether lethal or only damaging)
- Damaging or lethal effects on non-mammalian systems
- Some significant undesirable change in man, such as carcinogens, teratogens, or mutagens.

(4) Hazardous Materials List

The list of hazardous materials developed in this study (see page II-29) was assembled in a three-step process. First, as the literature was reviewed, search was made for reference by the various authors to identify:

- Materials commonly accepted as dangerous to man and the environment
- Materials which might present difficult disposal problems
- Materials known or suspected to have the ability to cause environmental damage
- Materials for which treatment and disposal processes were the subject of research efforts
- Materials involved in accidents.

The identities were recorded for all materials discussed in the literature, so long as it appeared, even superficially at the outset, that they might be hazardous and therefore require special waste management techniques in disposal. From the general literature a list of approximately 175-200 hazardous materials was compiled.

In the second step, existing lists of hazardous materials published by various organizations (see page II-26) were obtained and reviewed. In general, it was found that these lists had been structured to include materials presenting fire or explosion hazards and human toxicity hazards, but from the viewpoint of safety in transportation, i.e., hazards that would result from transportation accidents. It was also found that many of the materials appearing on these lists had been placed there as a result of admitted subjective judgments on the part of the groups responsible. For this reason, it was determined that a basic criteria for including materials from the published lists onto the list developed in this study was that the material should appear on at least two of the published lists. Thus, the final developed list of hazardous materials represents an integration of materials turned up by the literature search and materials lists.

The final step in developing the hazardous materials list was to screen the materials against toxicity and other effects references to determine whether sufficient hazardous effects information was available to justify inclusion of each material on the final list.

(5) Hazardous Effects Determination and Rating

The available literature reveals a wide range of effects of various materials that have been observed as a result of planned experiments involving laboratory animal and plant (vegetation) exposures to varying concentration levels and exposure time periods, and observations resulting from accidents. Industrial health studies also show a wide range of observed health effects, both acute and chronic, resulting from worker exposures to various materials.

Despite the many observations of effects reported by both the practicing medical community and research scientists, it was found that the contributing concentration levels are generally not documented—because they are unknown. This is true of observations made in industrial work places and in investigations of accidents. The problem of effects on humans is an especially difficult area since few human-subject experiments are conducted. and while good data have been obtained in controlled experiments with laboratory animals, the extrapolation of these results to human effects continues to be an area of great uncertainty. Research results from similar experiments frequently differ, and thus cast doubt on the validity of human extrapolation.

Further difficulty arises from the fact that observations of toxic effects on humans have been made for a relatively limited number of materials, with emphasis having been given to the metals and some metallic compounds. Very little data has been taken concerning plants and animals in their natural habitat. Plants suffer especially in this regard because, until very recent years, little research has been done to determine effects of materials on plants. Even the research done recently has been limited to a few compounds (e.g., oxides of sulfur, oxides of nitrogen, pesticides, herbicides).

In the end, the result is that the body of knowledge of hazardous effects of materials on man and the environment is essentially limited to acute (short-term) effects, much of it based on after-the-fact medical observations rather than predictions based on experimental results. An extremely serious gap remains in the knowledge of chronic (long-term) effects of materials on man or the environment. Laboratory-type research into chronic effects has been, for all practical purposes, nonexistent and the research that has been done has taken the form of long years' collection and analysis of case histories by individuals in the medical profession.

Pressed with the need to establish reasonable bases for the protection of health and safety, the medical community has promulgated guidelines in the form of data describing concentration exposure limits (threshold limits) for many materials, for both humans and animals. These values are useful in developing a method for rating the hazardous effects of materials. The rating method developed during this study is based on these guidelines (see Chapter IV), but takes additional factors into account as well.

It is also a flexible rating system which actually includes several types of ratings:

- Total Effects Rating (TER), basic rating developed from known effects, with allowance for weighting based on priorities
- Maximum Potential Effects Rating (MPER), a rating which includes the TER and an allowance for unknown effects
- Hazard Extent Rating (HER), a rating which represents material pervasiveness as a function of production and distribution
- Hazard Rating (HR), an overall rating which is the product of TER times HER
- Maximum Potential Hazard Rating (MPHR), an overall rating which is the product of MPER times HER (produces the highest overall rating score).

Principal among the additional factors are the media (air, water, land) wherein the hazardous materials might be transmitted to man and the environment, since the nature of the effects are dependent upon the nature of the contact between the material and the "host" (e.g., ingestion, respiration, surface contact). An important aspect of the media viewpoint is that it permits direct correlation with the disposal media when the hazardous materials become wastes requiring disposal.

For each hazardous material on the final listing (Chapter II), air disposal, water disposal, and land disposal were considered and for each medium, rating values were assigned which numerically express the level of severity of effects in three classes:

- Human toxicity effects
- Flame/explosion effects
- Ecological effects.

Table I-1 below indicates the nine basic factors assigned rating values.

Table I-1
Matrix of Factors for Rating the Level of Effects for the List of Hazardous Substances

Medium For Disposal	Hazard in Terms of Potential Effects		
	Human Populations		Eco Populations
	Toxic Effects (T_H)	Flame/Explosion/ Reaction (F_H)	Toxic Effects (T_F)
Air (A)	AT_H	AF_H	AT_E
Water (W)	WT_H	WF_H	WT_E
Soil (S)	ST_H	SF_H	ST_E

The numerical values assigned to each factor above were selected on a scale of 1-3, as follows:

3 - Severely hazardous

2 - Slight to moderate hazard

1 - Minimal hazard

U - Effects unknown.

The resultant scores for the nine individual factors were weighted, then summed to produce the basic rating score, here termed the Total Effects Rating (TER), which comprises the "known effects" rating.

In cases where effects are unknown or where data is not available, a value of three (maximum hazard value) was assigned to each "U" on the assumption that it would be desirable to produce conservative final ratings, especially for materials with a high number of unknowns. Adding these U-scores to the basic Total Effects Rating produces the Maximum Potential Effects Rating.

It is recognized that the scale of 1-3 is a narrow band likely to produce ratings that tend to group many materials into clusters in the overall rating scale, and that a wider spread in the relative ratings would be desirable. However, the limitations noted earlier with respect to knowledge of human and ecological effects of materials are such that the rating precision needed for use of a wider scale (e.g., 1-10), or the precision that would be implied if a wider scale were imposed, are not justified by the data available.

A final element that needs to be considered in rating materials according to hazardous effect is the concept of a "Hazard Extent Rating," which reflects the opportunity for the effects to occur. Many materials exist whose effects are severe and well-known, but which are neither produced in large quantities nor are widely distributed; thus, they present a localized and limited hazard problem, in terms of geographic area and population affected. Many other materials, however, whose effects might be lesser on a pound-for-pound basis, can pose a much more pervasive hazard problem if they are produced in very large quantities, and see widespread distribution and use throughout the economy. Pursuing this concept, values were assigned to ranges of production quantities (where production data is available) and to distribution, the latter indicating the extent of national distribution.

Table I-2 provides an example of the rating development. Table IV-18 (Chapter IV, page IV-25), shows the hazardous effects ratings for the list of hazardous materials developed in this study.

(6) Quantification and Location of Hazardous Materials

One of the fundamental purposes of this study was to provide information that would be useful in the overall EPA context of identifying materials that might require special waste management techniques in disposal because of their potential hazardous effects, and in the more specific context of the possible need for a national disposal site system for such materials. Among the desired results was quantification data describing the waste quantities and their geographic locations.

The literature search revealed, however, that waste quantification for specific materials does not exist. Among the principal reasons for this situation are:

- Historically, there has been no interest or objective in quantifying waste amounts of specific materials, with the exception of radioactive wastes, which are subject to a stringent control system
- For certain materials, such as pesticides and herbicides, the utilization and disposal cycles were one and the same, but geographic location data were not recorded
- In nearly all waste disposal processes, whether industrial, governmental, or domestic, materials being wasted are thrown together and become streams of mixed wastes

Table I-2
Sample Worksheet for Computing Substance Hazard Rating

Compound Aluminum Sulfate

		Initial Rating	Weight	Final Rating
Air Disposal	Human toxic effects	3	1	3
	Flame/Explosion	2	1	2
	Ecoeffects	3	1	3
Water Disposal	Human toxic effects	3	1	3
	Flame/Explosion	2	1	2
	Ecoeffects	2	1	2
Soil Disposal	Human toxic effects	3	1	3
	Flame/Explosion	2	1	2
	Ecoeffects	U	1	U
Total Effects Rating (Sum of above)				20
Number of Unknowns above				1
Maximum Potential Effects Rating	(unknowns x 3 plus total effects rating)			23
Production rating				1.5
Distribution Rating				0.5
Hazard Extent Rating	(Sum of Production & Distribution)			2.0
Hazard Rating	(Total Effects Rating x Extent of Hazard Rating)			40
Maximum Potential Hazard Rating	(Max. Potential Effects Rate & Extent of Hazard Rating)			46

- Pre-disposal waste treatment, where employed at all, has been applied to a limited number of waste stream characteristics, rather than to characteristics of specific materials.

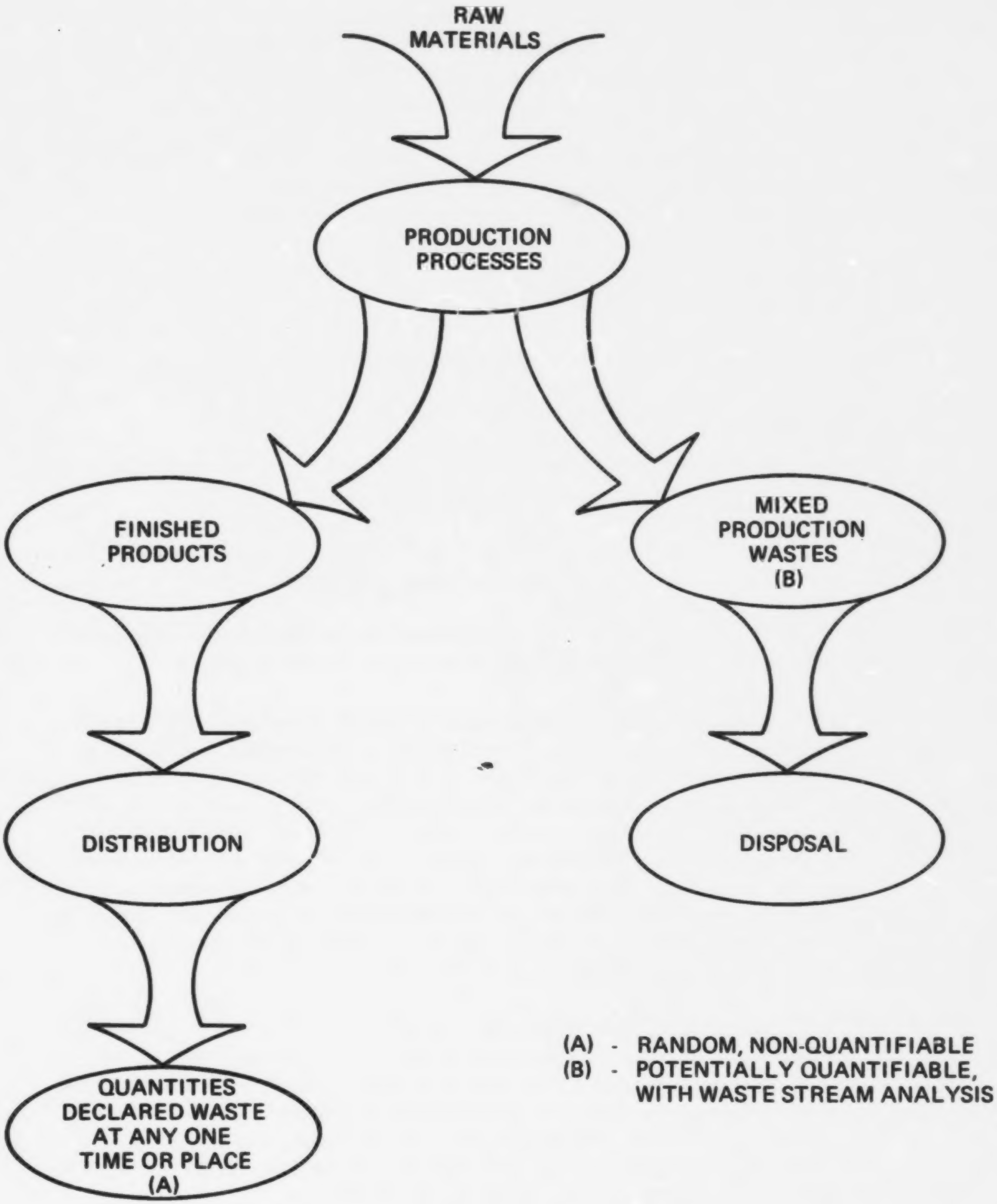
It follows that without waste quantity data for specific materials, geographic location cannot be considered. The impact of the latter two factors above on the hazardous waste quantification problem cannot be overstated. The difficulties imposed can be more succinctly observed when it is noted that mixed waste streams:

- Can have hazardous materials as inputs,
- Are not analyzed in detail, if at all,
- Might be chemically indeterminate, as a result of unknown reactions,
- Might exhibit some, all, or none of the characteristics of individual input materials, and
- Might become hazardous in itself through combinations of nonhazardous input materials.

Investigation of the overall problem of quantifying waste hazardous materials has to consider the problem of disposing of such materials in their pure (or relatively pure) form as well as in waste streams. Many of these materials are created as (or in) marketable products not meant to be wasted, yet for various reasons (shelf-life, contamination, etc.) at some time become wastes. In such cases, however, someone has to declare them to be no longer needed and thus ready for disposal. This waste quantification problem is graphically compared to the mixed waste problem in Figure I-1.

In addition to the literature search, attempts were made through industry associations, federal government agencies, and individual plants to collect the needed data. Some success was achieved through the government agencies. The industrial sector remains a problem area, for reasons discussed previously in Section (2), yet that sector is the major producer, user, and distributor of hazardous materials.

FIGURE I-1
The Hazardous Materials
Waste Quantification Problem


RAW MATERIALS
PRODUCTION PROCESSES
FINISHED PRODUCTS
MIXED PRODUCTION WASTES (B)
DISTRIBUTION
DISPOSAL
QUANTITIES DECLARED WASTE AT ANY ONE TIME OR PLACE (A)
(A) - RANDOM, NON-QUANTIFIABLE
(B) - POTENTIALLY QUANTIFIABLE, WITH WASTE STREAM ANALYSIS

Lacking factual data, then, the alternative is to develop a computation method for estimating waste quantities. This has been done, but is limited to estimating total waste quantities for industry types (by SIC code). These estimates were made by industry types for each of the 50 states and for each of the 50 largest Standard Metropolitan Statistical Areas (SMSA), and are listed on Tables III-5 and III-6 (Chapter III, pages III-14 and III-19).

To estimate these total waste quantities, a series of "waste factors" were calculated (one for each industry type) which represent the amount of wastes generated per 1,000 pounds of product (WPPP). Data were then extracted from the Census of Manufactures which show, for regions, SMSAs, and states, the production and value added in production by each industry. These data were reduced to value added per 1,000 pounds of product (VAPP). Then:

$$\frac{\text{WPPP}}{\text{VAPP}} = \frac{\text{lb. waste/1,000 lb. product}}{\text{\$ value added/1,000 lb. product}} = \frac{\text{pounds waste}}{\$},$$

and:

$$\frac{\text{Pounds waste}}{\$} \times \text{Total \$ value added} = \text{Total lb. waste}$$

Early in the study it was determined that of the 231 SMSAs in the country, the 50 largest account for approximately 60 percent of American industry. The remaining 181 would account for no more than 20 percent of industry. Thus, the arbitrary break was made at the top 50. From that point, total wastes estimates were made on a state basis since all industry could be accounted for in that manner. Further, in some states (e.g., Florida) which have few SMSAs, the bulk of industries of interest would not be included in the SMSAs in any event.

With respect to the potential national disposal site system, the value of approaching the quantification problem by studying the 50 largest SMSAs is that it demonstrates where the greatest quantities of wastes are generated which can include hazardous materials, and therefore indicates the locations that would most likely need to be served by such disposal sites. The wastes estimates by industries and states can readily be correlated with the hazardous materials information indicating which industries use which materials. From that point it is not difficult to identify the locations within the states (but outside of SMSAs) where the more important industries are situated, and therefore to determine other potential disposal site locations.

The remaining waste quantification problem regarding hazardous materials is to arrive at some means of determining what portion of the total wasteloads is composed of hazardous materials. The lack of such data, particularly in the critical industrial sectors, however, makes development of any reasonable estimating method highly improbable, if not impossible. This stems from the almost universal waste handling practice of collecting many plant wastes into common streams of mixed wastes. The problem is especially acute with respect to liquid wastes and for many solids which are put into solution for waste handling purposes, since such wastes typically include the chemical compounds that are among the most hazardous of materials. A limited amount of information was obtained, however, which provides rough quantification factors indicating the generation of certain commonly-known (by "trade" names) waste streams as a function of production. In some cases, these quantification factors also show typical amounts of specific hazardous materials contained in those waste streams. Where such data were available, estimates of total waste stream production and estimates of contained hazardous materials were computed. The results are presented in Table III-7 (Chapter III, page III-29).

(7) Hazardous Materials Accident Data

In searching the literature for accident data involving hazardous materials, the objective was to identify sources of statistical data for:

- Accident reports (e.g., frequency, apparent causes, human factors, effects)
- Materials involved in accidents (e.g., hazardous material properties, material weights or volumes, container characteristics)

- Disposal problems (e.g., effects of quantity; characteristics of the environment such as meteorological conditions and terrain features including soil, vegetation, and drainage pattern; details of handling problems such as salvage possibilities and specific handling instructions).

While some accident data were discovered with respect to waste materials (and are discussed as part of the industry descriptions in the appendices), such information is extremely scarce, and reports or articles are written only when the accidents are spectacular. Thus, minor accidents or accidents that may have latent effects, because of the materials involved, are not routinely reported. Beyond the literature search, various organizations concerned with safety and accident prevention (e.g., National Safety Council, Navy Safety Center) were contacted, but were unable to shed light on the subject. It appears that there are no organizations, public or private, which make a routine practice of collecting and analyzing accident data involving hazardous materials, with the exception of transportation interests.

Hazardous materials accidents involving public transportation are reasonably well reported. However, such accidents present no surprises, since the materials involved are in pure form (as marketed products), and their effects are known in advance. Therefore, the transportation community seeks to prevent accidents, and new knowledge rarely, if ever, evolves from investigation of these accidents.

A full discussion of the situation surrounding hazardous materials is given in Appendix A-6 through D-2 (Volume III).

(8) Disposal Practices

Disposal practices for hazardous materials are discussed in detail in Chapter V. These practices involve two important considerations, depending upon whether the materials are in pure form or represent some portion of mixed waste streams.

The only adequate published information describing disposal methods for hazardous materials in pure form is that available from the Manufacturing Chemists Association, and representative listings are presented in Chapter V (see page V-77). In the automatic data processing records developed for this study, the appropriate MCA-recommended disposal technique is given for each of the hazardous materials on the final list (Chapter II). These methods can apply whenever the materials must be disposed of in pure form, in answer to the finished product question discussed previously in Section (6).

The real, but undefined, problem which remains, however, is the treatment and disposal of waste streams having hazardous materials as partial inputs. The common practice is to analyze waste streams for only a few characteristics, and to treat the streams based on these results, if the streams are treated at all, prior to disposal. Since the mixed wastes are not analyzed in detail, little or nothing is known about what actually happens, in terms of reactions and the resultant detailed characteristics of the waste streams. It follows that knowledge does not exist which can reveal the possible hazardous nature of the wastes discharged after treatment. The preponderant media used to dispose of wastes are landfill and discharge to surface waters (rivers, lakes, oceans), and the medium selected is based on economics rather than on environmental protection.

A final objective of the study was to determine the extent to which manufacturers of hazardous materials provide disposal instructions as a part of package labeling. The literature search and discussions with industry sources both revealed that disposal instructions are not made a part of labeling practice. Further, the consensus among manufacturers is that such instructions should not be put on labels, for the reason that many handlers or users are not knowledgeable enough concerning the nature of the materials, can too easily misinterpret the instructions, and cause serious harm to themselves and others.

For these reasons, the manufacturers, particularly the chemical companies, prefer that users return hazardous materials for disposal. For many years, these manufacturers have provided the return service with regular points of contact identified to the users. Recently, in a cooperative effort among the chemical firms and the Manufacturing Chemists Association, the materials return services have been placed under the jurisdiction of MCA, with a "hot line" established so that quick response can be made to special problems.

4. CONCLUSIONS AND RECOMMENDATIONS

(1) Principal Conclusions

Key conclusions resulting from this study include:

- At present a comprehensive body of knowledge which describes the hazardous effects of most substances does not exist.
- Little evidence was obtained to indicate that current disposal methods are creating a human health hazard. Environmental damage is more likely to occur than are health hazards to humans.
- A review of disposal processes established the existence of a variety of useful technology, and more importantly, the fact that much of the technology is not widely used.
- The development of a list of hazardous substances is not equivalent to the development of a list of hazardous wastes because of the many unknowns with respect to industrial mixed waste streams.
- Wastes to be hazardous must contain one or more hazardous substance in sufficient concentration to be detrimental to human health or other elements of the ecological system.
- Accurate characterization of waste streams is essential to the evaluation of hazard potential and the design of waste treatment to abate such hazards.

- Disposal of hazardous materials is best handled at the point where the hazardous material is produced (process) or released (plant).

These conclusions are presented in greater detail in Chapter VII.

(2) Recommendations

The principal recommendations resulting from this study are:

- A national control system is needed and should be developed for designated hazardous materials and wastes. The control system should include:
  - Identification of critical waste processes or products
  - Licensing of production and disposal processes
  - Specification of handling and treatment methods
  - Inspection for conformance
  - Prescriptions for labeling of warnings and disposal methods
  - Designation of collection points for specific waste categories requiring special handling
  - Licensing of contractors for disposal or recycling
  - Designation of ultimate disposal methods
  - Development of implementation plan.
- Special disposal sites should be designated or developed only if needed in the context of a comprehensive hazardous waste control system.

- Packaged hazardous consumer products should be controlled throughout their distribution cycle, and residential containers collected for reuse or approved disposal.
- Indepth studies should be made of a selected number, say 10 to 15, of hazardous materials based on highest production quantities and widest distribution.
- The recommended studies should include investigation of production, distribution, and disposal patterns for the selected materials.
- A major research effort should be implemented toward the specific task of identifying the hazardous effects of various materials. This research effort should give major consideration to long-term (chronic) effects.
- An extensive set of criteria needs to be developed for defining hazardous materials, including hazardous wastes.
- Extensive research is needed for determination of the composition of industrial waste streams.
- Waste treatment research is needed to establish the feasibility of separating certain hazardous compounds from general waste streams (e.g., heavy metal wastes, phenols).

II. IDENTIFICATION OF HAZARDOUS MATERIALS

1. INTRODUCTION AND DEFINITIONS

Fundamental to the development of a plan which will recommend ways to handle and dispose of wastes involving hazardous materials is the development of an extensive list of materials, compounds, or products which require special handling techniques. A hazardous substance list should take into account all important characteristics of substances which could cause them to be or to become hazardous. The hazard consideration should include not only people but also all ecological subsystems which contribute to environmental balances. The list should include hazards that may develop in all disposal media (i. e., air, water, or soil). From such a list it will be possible to develop insight into the total problem and to recommend preliminary approaches for handling the wide variety of hazardous wastes which are generated.

At present, a list of hazardous substances (for waste management purposes) that would be all inclusive cannot be developed because of the state of knowledge limitations in many of the hazardous waste material areas. In particular, the potential range of adverse effects that may be produced by hazardous wastes on a variety of receptors (which include humans, animals and plants) is not fully known. It is imperative, however, that any tentative list be as representative as possible of the real world situation.

The analytical approach followed in this study for the development of a hazardous substance list includes:

- Literature surveys of waste disposal techniques, the associated wastes, and previously published lists of hazardous materials
- Direct interviews with persons having knowledge of current waste problems and procedures

- Identification of hazardous material manufacture and use by industrial sectors.

Definition of hazardous materials remains a problem. Initially, for the purposes of this study, hazardous wastes were defined as follows:

> "Hazardous waste materials are defined as those materials or combinations of materials which require special management techniques because of their acute or chronic effects on the health or welfare of the public (or those individuals who handle them when they are disposed of by waste management processes (e. g., storage, transport, incineration, sanitary landfilling, composting, dumping, industrial waste treatment))."

Although necessarily imprecise, this general definition will serve to outline the complexity of the problem of management of chemical wastes in that these will almost always, by definition, contain some materials which may, as are, or under conditions of waste management, become injurious to public health and public welfare. This can best be understood by examination of the concept "hazardous waste" and of the definition given earlier.

The use of the adjective hazardous, defined as "left to chance" implies that there are liabilities, potential problems, or risk probabilities in the operation which is being described; in this case, waste management. All chemical wastes have some hazard (some risk probability) of becoming dangerous on disposal. These may vary from minimal dangers such as salt dumping at sea, which damages osmotic pressure of the microenvironment, with possible liabilities on local life, to such indescribable potential problems as disposal of nitrite dumping which may interact with other chemical species to form nitrosamines (known carcinogenic) which may finally appear in drinking water, to such clearly defined problems as mercury or acid dumping. The problem is the characterization of the "hazard potential" and the subsequent selection of some point below which the potential is so minimal as to be arbitrarily defined as negligible. Then, only those wastes which have hazard potentials above this point could be considered as candidates for special handling, treatment and disposal.

Obviously, the characterization of "hazard potential" is based on a number of factors, which can be arbitrarily assigned some importance.

(1) Route of Disposal

Some materials will vary in hazard based on the final disposition. Readily biodegradable toxic or otherwise unwanted materials from which no dangerous species of chemicals can be produced will be nonhazardous if put into an efficient sewage treatment plant, but highly suspect if disposed of at sea or in a watercourse, or by some technique through which the original materials can appear in ground or drinking water. Biodegradable surfactants are examples of this type of material. For the purposes of this report, this factor has been minimized, assuming that the basic unchanged character is the point of focus and not the potential deactivation in special treatment situations.

(2) Mammalian Toxicity

Obviously, this is a key factor in consideration of hazard potential. Basically toxic materials such as cyanide, heavy metals, fluorides, radioactive wastes, etc., must be considered as hazardous. These can affect all forms of life in the disposal process or in the ultimate disposal media. Again, arbitrary assignments can be made on the basis of current knowledge of toxicity. Those materials which are defined in law (The Federal Hazardous Substances Act, The Hazardous Materials Board of the Department of Transportation) as very toxic (oral toxicity to rats, LD_{50} of 50 mg per kg or less) or highly toxic (LD_{50} of 50 to 500 mg per kg) should be considered dangerous. Waste streams which contain such materials, regardless of concentration, should also be labeled "hazardous."

(3) Non-Mammalian Toxicity

This is a much less clear concept, since less is known about effects of materials on fish, birds, etc. Nevertheless, some factor such as that given above for the mammals is needed.

(4) Chemical and Biochemical Change

Prior to this decade, the scientific community did not recognize secondary hazard liability where materials can undergo chemical or free radical changes in the environment, or under special microenvironmental conditions, to become species which have greater hazard liability. Now these changes are commonly recognized; for example, the mercury conversion to methyl mercury, the photo-oxidation of hydrocarbons, or the anaerobic conversion of nitrilotriacetate to nitrosamines. Where such change can occur, then, the waste must be considered as hazardous and processed to remove the potentially labile species.

(5) Imbalances

Some materials, phosphates may well be the most readily recognized offender at present, may cause imbalances when added to the microenvironment. These imbalances may result in changes in the food chain of a waterway, the economic value of the ultimate disposal site, or the health value of land or water. For example, disposal of large amounts of sodium ion into a watercourse, resulting in its appearance in a drinking water system, could cause a change in the propensity of the consuming population for cardiovascular disease. Thus, imbalance too should be considered.

For the purposes of this study, the tendency has been to ignore this problem, as has the question of route of disposal. Where the material classified as waste is neither inherently toxic nor dangerous, imbalance alone is not a factor in causing assignment of a hazardous rating.

(6) Miscellaneous Factors

Occasionally, it must be recognized that materials can be offensive because of their non-biological effects. Materials can be visualized which cause structural degradation, offensive but not injurious odors, unsightly accumulation, etc. For the purpose of this analysis, these were also not termed "hazardous" despite the fact that improved disposal practice may benefit the public good.

In summary, materials have been defined as hazardous if they have the known inherent ability to produce:

- Toxic effects on mammalian species (whether lethal or only damaging)
- Damaging or lethal effects on non-mammalian systems
- Some significant undesirable change in man, such as carcinogens, teratogens, or mutagens.

2. APPROACH TO HAZARDOUS MATERIALS IDENTIFICATION

The approach outlined in the preceding section was implemented for the study. An extensive literature search was conducted which included both manual and computer screening of pertinent literature sources to identify useful references (see pages I- 4 to I- 7). While the literature search covered all aspects of information applicable to the study, simultaneously, emphasis was placed on identification of hazardous materials, since all other aspects (e. g., handling, treatment, disposal) had to be related to the materials. It should be noted that no preconceived notions were held as to what materials might be hazardous. Rather, any materials that were identified were initially listed, then cross-checked through references describing hazardous properties of materials to determine whether they should remain on the list.

As the literature was reviewed, it became apparent that certain industry types constitute the principal manufacturers and users of potentially hazardous materials, and experienced many environmental pollution problems. Therefore, it was determined that the collected information could be handled most systematically if it were categorized according to industry groups. To complement the industry group identification indicated by the literature, reference was made to a listing entitled "Major Sources of Pollution," which was developed during 1967-1968 by the Federal Water Pollution Control Administration. That list covers the top 50 pollution sources (from the viewpoint of water use), and includes natural and nonindustrial sources. In addition, the list presents a priority ranking indicating the relative severity of the pollution problems created by the sources named. The list is reproduced in Table II-1.

Comparisons were made between the industries listed by Table II-1 and the industry-type identities indicated through the literature search, and a list of industry groups was developed for use in categorizing

Table II-1
Major Sources of Pollution ‡

No.	Source	Priority	PPBS Category
1	Pulp & paper industry	1	1204
2	Municipal sewered waste	2	1101
3	Power (thermal) production	3	1203
4	Agriculture runoff	4	1302
5	Storm & combined sewers	5	1102 1103
6	Food processing industry	6	1206
7	Petrochemical industry	7	1202
8	Irrigation return flow	8	1303
9	Petroleum refining industry	9	1205
10	Feed lots	10	1304
11	Metal & metal products industry	11	1201
12	Unsewered domestic waste	12	1105
13	Marine	13	1501
14	Dredging	14	1507
15	Oil pollution & production	14	1402
16	Organic chemical industry	14	1202
17	Acid Mines	15	1401
18	Impoundments	16	1504
19	Recreation boats	16	1501
20	Unsewered urban runoff	17	1104
21	Textile industry	18	1209
22	Inorganic chemical industry	19	1202
23	Commercial vessels	20	1502
24	Construction activities	21	1503
25	Potato processing	22	1206

Table II-1
(Continued)

No.	Source	Priority	PPBS Category
26	Pharmaceutical manufacture	23	1202
27	Pesticide industry	24	1202
28	Saltwater intrusion	25	1505
29	Phosphate mining	26	1404
30	Logging	27	1301
31	Milk products & handling	28	1206
32	Fertilizer manufacture	29	1202
33	Fish processing industry	30	1206
34	Lumbering	31	1210
35	Mining	32	1404
36	Coal processing	33	1205
37	Strip mining (coal, sand & gravel)	34	1404
38	Uranium mining	35	1403
39	Meat packing	36	1206
40	Natural pollution	36	1506
41	Canning industry	37	1206
42	Sugar beet industry	37	1206
43	Cattle industry	37	1304
44	Brines	38	1212
45	Copper mining	39	1404
46	Log storage	39	1210
47	Agricultural chemical production	40	1202
48	Tanning & leather industry	41	1212
49	Nuclear installations	41	1212
50	Brewery wastes	42	1206

‡ Developed 1967-1968 By Federal Water Pollution Control Administration

the study information (Table II-2). These industries are identified by their Standard Industrial Classification (SIC) code numbers. A distinct advantage of this approach is its use of geographically locating (through reference to the Census of Manufactures) the major hazardous material use-points, and consequently the location of potentially hazardous wastes. The industry group list was also supplemented by identity of federal government agencies most concerned with the manufacture and use of hazardous materials, and with the category of power utilities.

The SIC code listing of Table II-2 breaks down to the four-digit codes where the industry group identification becomes more specific than is indicated by the two-digit general codes, and it was to the four-digit level that the initial literature search was directed. However, the extent and quality of information available proved to be so limited that, with a few exceptions, the more realistic approach was to utilize the two-digit codes for aggregating and reporting purposes.

As the industry groups were identified, the more prominent trade associations representing each industry were also identified. Contacts were made with 20 such associations (Table II-3) to determine whether they were publishing any materials involving wastes, waste disposal, or hazardous materials data. There were a few notable exceptions, but, as a rule, these groups were unable to provide assistance. Many have undertaken either no specific technical work or have only recently become involved in technical matters related to the environmental pollution problems of their member firms. Those able to provide information were the larger and more technically oriented groups (e.g., American Petroleum Institute). A limited number of visits were made to industrial plants since the study program did not envision an extensive survey effort, but little factual information was gained from these sources. A survey was made among nine hospitals in the New York-New Jersey area, and the results are reported in Appendix A-11 but little worthwhile information was gained with respect to pathological and other potentially hazardous materials as wastes.

Key findings of these early discussions and data collections included the following:

- Detailed information on the composition of industrial waste streams could be located for only a few representative industries or single processes within an industry.

Table II-2
Standard Industrial Classification (SIC) Used for Information Categorization

SIC Code and Title

10		Metal Mining
11		Anthracite Mining
12		Bituminous Coal and Lignite Mining
20		Food and Kindred Products
	2011	Meat Packing Plants
	2013	Sausages and Other Prepared Meats
	2015	Poultry Dressing Plants
	2021	Creamery Butter
	2022	Cheese, Natural and Processed
	2023	Condensed and Evaporated Milk
	2024	Ice Cream and Frozen Desserts
	2026	Fluid Milk
	2031	Canned and Cured Seafoods
	2032	Canned Specialties
	2033	Canned Fruits and Vegetables
	2034	Dehydrated Food Products
	2035	Pickles, Sauces and Salad Dressings
	2036	Fresh or Frozen Packaged Fish
	2037	Frozen Fruits and Vegetables
	2041	Flour and Other Grain Mill Products
	2042	Prepared Feeds for Animals and Fowl
	2043	Cereal Preparations
	2044	Rice Milling
	2045	Blended and Prepared Flour
	2046	Wet Corn Milling
	2061	Raw Cane Sugar
	2062	Cane Sugar Refining
	2063	Beet Sugar
	2071	Confectionery Products

Table II-2
(Continued)

	2072	Chocolate and Cocoa Products
	2073	Chewing Gum
	2082	Malt Liquors
	2083	Malt
	2084	Wines, Brandy and Brandy Spirits
	2085	Distilled Liquor, Except Brandy
	2086	Bottled and Canned Soft Drinks
	2087	Flavoring Extracts and Syrups, N. E. C. *
	2091	Cottonseed Oil Mills
	2092	Soybean Oil Mills
	2093	Vegetable Oil Mills, N. E. C. *
	2094	Animal and Marine Fats and Oils
	2096	Shortening and Cooking Oils
	2095	Roasted Coffee
	2097	Manufactured Ice
	2098	Macaroni and Spaghetti
	2099	Food Preparations, N. E. C. *
22		Textile Mill Products
	2211	Weaving Mills, Cotton
	2221	Weaving Mills, Synthetics
	2231	Weaving and Finishing Mills, Wool
	2241	Narrow Fabric Mills
	2251	Women's Hosiery, Except Socks
	2252	Hosiery, N. E. C.
	2253	Knit Outerwear Mills
	2254	Knit Underwear Mills
	2256	Knit Fabric Mills
	2259	Knitting Mills, N. E. C. *
	2261	Finishing Plants, Cotton
	2262	Finishing Plants, Synthetics

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[*] Not Elsewhere Classified

Table II-2
(Continued)

	2269	Finishing Plants, N. E. C.*
	2271	Woven Carpets and Rugs
	2272	Tufted Carpets and Rugs
	2279	Carpets and Rugs, N. E. C.*
	2281	Yarn Mills, Except Wool
	2282	Throwing and Winding Mills
	2283	Wool Yarn Mills
	2284	Thread Mills
	2291	Felt Goods, N. E. C.*
	2292	Lace Goods
	2293	Paddings and Upholstery Filling
	2294	Processed Textile Waste
	2295	Coated Fabrics, Not Rubberized
	2296	Tire Cord and Fabric
	2297	Scouring and Combing Plants
	2298	Cordage and Twine
	2299	Textile Goods, N. E. C.*
26		Paper and Allied Products
	2611	Pulp Mills
	2621	Paper Mills, Except Building Paper
	2631	Paperboard Mills
	2661	Building Paper and Board Mills
28		Chemicals and Allied Products
	2812	Alkalies and Chlorine
	2813	Industrial Gases
	2815	Cyclic Intermediates and Crudes
	2816	Inorganic Pigments

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*Not Elsewhere Classified

Table II-2
(Continued)

	2818	Industrial Organic Chemicals, N. E. C.*
	2819	Industrial Inorganic Chemicals, N. E. C.*
	2821	Plastics Materials and Resins
	2822	Synthetic Rubber
	2823	Cellulosic Manmade Fibers
	2824	Organic Fibers, Noncellulosic
	2831	Biological Products
	2833	Medicinals and Botanicals
	2834	Pharmaceutical Preparations
	2841	Soap and Other Detergents
	2842	Polishes and Sanitation Goods
	2851	Paints and Allied Products
	2861	Gum and Wood Chemicals
	2871	Fertilizers
	2872	Fertilizers, Mixing Only
	2879	Agricultural Chemicals, N. E. C.*
	2892	Explosives
	2895	Carbon Black
29		Petroleum and Coal Products
	2911	Petroleum Refining
	2951	Paring Mixtures and Blocks
	2952	Asphalt Felts and Coatings
	2992	Lubricating Oils and Greases
	2999	Petroleum and Coal Products, N. E. C.*
31		Leather and Leather Products
	3111	Leather Tanning and Finishing
	3121	Industrial Leather Belting
	3131	Footwear Cut Stock

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*Not Elsewhere Classified

Table II-2
(Continued)

33		**Primary Metal Industries**
	3312	Blast Furnaces and Steel Mills
	3313	Electrometallurgical Products
	3315	Steel Wire and Related Products
	3316	Cold Finishing of Steel Shapes
	3317	Steel Pipe and Tubes
	3321	Gray Iron Foundries
	3322	Malleable Iron Foundries
	3323	Steel Foundries
	3331	Primary Copper
	3332	Primary Lead
	3333	Primary Zinc
	3334	Primary Aluminum
	3339	Primary Nonferrous Metals, N. E. C.*
	3341	Secondary Nonferrous Metals
	3351	Copper Rolling and Drawing
	3352	Aluminum Rolling and Drawing
	3356	Nonferrous Rolling and Drawing, N. E. C.*
	3357	Nonferrous Wire Drawing and Insulating
	3361	Aluminum Castings
	3362	Brass, Bronze and Copper Castings
	3369	Nonferrous Castings, N. E. C.*
	3391	Iron and Steel Forgings
	3392	Nonferrous Forgings
	3399	Primary Metal Products, N. E. C.*
34		**Fabricated Metal Products**
	3471	Plating and Polishing
	3479	Metal Coating and Allied Services

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*Not Elsewhere Classified

Table II-2
(Continued)

80	Medical and Other Health Services
806	Hospitals
Atomic Energy Commission	
Department of Defense	
Power Utilities	

Source: Standard Industrial Classification Manual, Executive Office of the President, Office of Statistical Standards, U.S. Government Printing Office, 1967.

Table II-3
Trade Associations Contacted

1. Technical Association of Pulp & Paper
1 Dunwoody Park
Atlanta, Georgia 30341

2. American Electroplaters Society
56 Melmore Gardens
East Orange, New Jersey 07017

3. American Association of Textile Chemists & Colorists
Box 12215
Research Triangle, North Carolina 27709

4. American Textile Manufacturing Association
Charlotte, North Carolina

5. American Paper Institute
260 Madison Avenue
New York, New York 10016

6. National Association of Metal Finishers
248 Lorain Avenue
Upper Montclair, New Jersey

7. Institute of Makers of Explosives
420 Lexington Avenue
New York, New York 10017

8. Manufacturing Chemists Association
1825 Connecticut Avenue, N. W.
Washington, D. C. 20009

9. American Petroleum Institute
1801 K Street, N. W.
Washington, D. C.

10. National Agricultural Chemicals Association
1155-15th Street, N. W.
Washington, D. C.

Table II-3
(Continued)

11. Fertilizer Institute
1015-18th Street
Washington, D. C.

12. Sulfur Institute
1725 K Street
Washington, D. C.

13. National Paint, Varnish and Lacquer Association
1500 Rhode Island Avenue, N. W.
Washington, D. C. 20005

14. National Petroleum Refiners Association
1725 DeSales Street, N. W.
Washington, D. C. 20036

15. American Petroleum Refiners Association
717 Ring Building
Washington, D. C. 20036

16. American Chemical Society
1155-16th Street, N. W.
Washington, D. C.

17. U.S. Can Sugar Refiners Association
1001 Connecticut Avenue, N. W.
Washington, D. C. 20036

18. American Pharmaceutical Association
2215 Constitution Avenue, N. W.
Washington, D. C.

19. National Pharmaceutical Council
1030-15th Street, N. W.
Washington, D. C. 20005

20. National Solid Waste Management Association
1145 - 19th Street, N. W.
Washington, D. C.

- The large masses of data needed to provide definitive information on specific, hazardous constitutents of industrial waste streams and waste piles was not available except as indicated previously.
- With definitive information on waste hazard characteristics and amounts lacking, the list of potentially hazardous waste materials must rely for definition upon certain limited, commonly-measured properties of waste such as acidity or alkalinity, biological oxygen demand (BOD), odors, radioactivity, etc.
- A substantial amount of useful information does exist relative to the toxic effects and explosive characteristics of many chemical elements and compounds (i. e., basic data not related directly to industrial products or industrial waste streams).

From the above findings, it was concluded that the development of a list of hazardous waste substances should proceed along two main lines. As originally planned, data relative to a list of waste materials was assembled by industry through detailed analysis of selected industrial sectors as defined by the Standard Industrial Classification Code (Reference 1). These lists included not only materials found in waste streams, but also materials believed to be hazardous and found as input materials (materials included in product process cycling), and materials included as products whether they were intermediate products or final products for consumer distribution and use.

It was expected (and confirmed) that the lists of potentially hazardous materials developed from industry references would include the identification of many materials or substances in generic or collective terms such as "solvents," "slimes," "oxidizers," etc. Specific chemical compounds or elements embraced by the generic categories were defined, to the extent possible, for each industry and/or by commonly employed industrial processes within each industry.

Simultaneously, a more basic list of known hazardous substances was compiled. The basic list evolved from data and information extracted from detailed study. These reports and references include biological data that resulted from experimental or accidental animal and plant exposures to various substances suspected of being toxic, explosive or otherwise hazardous to human and/or other forms of life.

Among the information assembled were also a number of reports which included lists of materials and compounds deemed hazardous for a variety of reasons, depending upon the purpose of each study (or mission of each group) that developed such a list. Many of the chemical substances included on these individual lists appeared on several of the lists, lending credence to the claims that they comprise a hazard. Substances included on more than one list were identified and became part of a nucleus to which other substances, identified as hazardous elsewhere in the literature, were added to complete the second, more basic, list of hazardous substances.

The dual approach, then, for the development of a list of hazardous materials was to assemble lists of hazardous materials based on industry references by specific chemical elements, compounds and substances, and concurrently review existing lists of hazardous materials prepared by major associations and government agencies (see Table II-4, page II-26). Relationships needed to be determined among the lists to establish the extent of hazard that prevails as a result of hazardous materials and wastes involved in industrial processes. Such relationships were to be established to the extent possible at available bridging points; that is, those industries and specific industrial processes for which representative or typical composition of product and waste materials have been made available.

Accordingly, emphasis was placed on establishing a comprehensive list of materials which require special handling and disposal, and on establishing techniques which would identify hazardous waste streams and the disposal processes they require. Additional data on disposal practices were gathered in terms of current industrial practices and available guidelines. Data were also collected on industrial production and consumption quantities. These latter data were developed further to provide a measure of the movement and geographical distribution of potentially hazardous materials which may:

- Be used in the closed production cycle of a single industrial plant
- Be produced as an intermediate product by one type of industrial plant for use as input material for other industries
- Be produced as part of a variety of consumer-type products which move freely in commerce on a nationwide (or even global) scale.

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By viewing patterns for the production and flow of materials known to be relatively hazardous (i. e., the basic list), it is possible to make some preliminary estimates of the magnitude and extent of corresponding hazard and disposal problems. The details of the development of the list of hazardous substances are documented in Section 5 (page II-24). All of the above described data and information became input to the development of a system for rating the individual items included on the list of hazardous substances. The development of this rating system is described in Chapter IV.

3. OCCURRENCE OF HAZARDOUS WASTES

Hazardous wastes involve materials discarded because they are either unneeded or unwanted, but which can have toxic effects on man or his environment in adequate controls are not exercised throughout their life-cycles, from initial extraction or production until final disposition. The concept of adequate control (management) of such materials is fundamental to an evaluation of hazardous materials disposal practices. The places and times when control over material passes from one responsible group to another are likely to be danger areas in this control system.

Each material which enters the economic system has a 'life style' of its own. Some are relatively simple; others may be quite complex. Coal, for example, may be extracted and consumed immediately in a local stove, or, it may be shipped to a major industrial site to initiate the production of a series of complex chemical compounds. At each stage in conversion processes, the possibility of hazardous wastes arises. Typically, control over potential hazards will be greatest when ownership interests are involved, and least when no ownership interest exists. The conversion of the material from one form to another also increases risks and requires close controls. Toxic materials may be produced where formerly no toxicity existed. These materials may be either main products, by-products, or waste materials with potentially significant environmental effects.

Hazardous waste materials occur in two general forms:

- Hazardous materials in the form of finished products, which are declared by the owner to have no further value and thus ready for disposal

- Hazardous materials which are generated as wastes from production or use processes, and immediately enter the disposal process.

The first type comprise materials whose characteristics and properties are known, and whose hazardous effects are known to some extent. Since they are originally manufactured as valuable, marketable products, and since they may pass through several ownerships during their lives, the time or place at which they may be declared waste is both unknown and unpredictable. Therefore, to protect man and the environment from adverse effects of careless disposal practice, a system of control is needed through which owners are continuously held accountable for the status of the materials.

The more pressing problem of hazardous wastes occurs as a result of production and use processes, since materials are represented which are generated routinely and continuously as wastes, are immediately ready for disposal, and are usually disposed of quickly. Production process wastes, with the exception of off-spec products, very seldom consist of pure materials and since they are wastes, are usually thrown together into mixed wastes. The properties of the input materials to mixed waste streams may be known, but very little is known, as a rule, of the hazardous properties of the waste stream, because detailed analyses of these streams are not made. Thus, the mixed waste stream might:

- Exhibit some or all of the characteristics of certain of its constituents

- Produce chemical reactions which are unknown and indeterminate

- Create, in the mixture, hazardous conditions greater than those attributable to any of its constituents

- Nullify, in the mixture, hazardous properties of any or all of the constitutents.

The fact that knowledge of these factors is not available contributes the greatest threat to the ecology today, since these mixed wastes are a daily fact-of-life, yet cannot be properly included in a list of hazardous materials since nearly nothing definitive is known about them.

The most toxic materials can be, and routinely are, safely controlled throughout their life cycles. Industry and government continuously produce, utilize and dispose of extremely toxic materials. Where the dangers are recognized and controls carefully engineered and operated, no hazardous conditions arise. The materials may present hazards if uncontrolled, but the controls applied assure that the occurrence of hazards is minimized.

The numbers of existing compounds that can have toxic effects on man or his environment are in the tens of thousands. New compounds are being developed daily. The knowledge we have of the ultimate toxic properties of present compounds is quite limited, and new compounds are likely to be developed more rapidly than are our capabilities to unravel their short- and long-term toxicities. Establishment of an ultimate list of compounds for designation as either hazardous materials or hazardous wastes is foredoomed. By the time the hazardous effects of the included compounds can be made known, the list will be outdated. This is particularly true in the consideration of chronic (long-term) effects, where the time required to ascertain the effects is measured in years, and frequently the materials are no longer produced or used by the time the results are known. The economic aspects of this situation have retarded chronic effects research, since even the most concerned parties are unwilling to commit the necessary resources to research in so uncertain a situation. Any selection and listing of hazardous materials, then, must be viewed as a useful sample from the universe of toxic materials, which can be utilized to evaluate existing management techniques (capabilities and limitations), and to assist in the development of management systems which will ensure better control over similar materials. It is in this context that the list of hazardous materials developed in this study should be viewed and utilized.

The investigations conducted during this study have explored both the toxic challenges to the environment which exist and the means now in use to control and safely dispose of materials having dangerous properties. As the study progressed and the concept of adequate controls assumed more significance, greater importance came to be attached to the capabilities of treatment and disposal systems to control hazards, than to the capabilities of the materials to create hazards. The best techniques and combinations of techniques now available can provide a means to devise a national control system over hazardous materials which will ensure safe handling throughout their life cycles, and safe disposition when their economic utility has been exhausted.

An additional problem exists that has significance to the way in which hazardous wastes are treated and disposed of—the problem of attitudes on the part of individuals. As discussions were held with representatives of industry and government, it quickly became apparent that many individuals are daily handling and disposing of hazardous materials (e.g., acids, caustics, pesticides), but who will flatly state that they are not involved with hazardous materials. Part of this problem stems from close familiarity with the materials handled, but the lack of clear-cut definition of hazardous materials contributes significantly to the problem.

4. ANALYTICAL PROBLEMS

Despite the apparent straightforward analytical approach, a number of analytical problems prevail that require attention. The definition provided initially by the EPA implies that the state-of-the-art includes quantitative measures of health or welfare effects caused by human exposures to hazardous wastes. However, relatively few of the many substances considered as potential toxic pollutants of the environment have been studied sufficiently to permit full definition of concentration and effects relationships, which may vary considerably as a result of numerous factors. In a limited number of cases, data are adequate to define the full spectrum of effects that may be obtained. In many instances, however, the effects criteria in common use are educated guesses at best. Many of the effluents of industrial society, while not specifically hazardous to humans or other populations, can exert slow but extensive changes to the ecology. Materials which have no discovered effect on man or his environment may impose unrecognized, subtle effects which can irreversibly disturb the genetic patterns of man or other living specie.

For such reasons, the identification and quantification of specific hazardous materials should be approached most cautiously. What is not known about material toxicology is immense. The proliferation of organic and inorganic compounds may exceed the capability of man to rigorously identify the hazards associated with each. As stated in the 1969 American Chemical Society Annual Report:

> "Several problem areas emerge as explicit themes in this report. One such theme is the primitive conditions of our fundamental knowledge of how living things are affected by long-time, low-level exposure to pollutants. Partly related to this theme is a second,

> the even more primitive condition of our knowledge of the effects of pollutants on the ecology, that is on the aggregate of living things as they exist in nature. The relationship of contaminants to the ecology is very nearly a total mystery. A third theme is the analytical methods that are used to monitor, control and study the environment and related phenomena. Those methods generally are not as good as they ought to be."

Not all hazardous effects are toxic. Some materials may cause biological effects (disease or illness), and an area of important consideration results from the flammable and explosive potential of some compounds (see References 2, 3, 4, 5, 6 at the end of this chapter). Other materials are capable of violent self-reaction or reaction with other compounds, including moisture or water (References 7, 8).

Not all effects resulting from hazardous substances, particularly as wastes, are direct and immediate. The fact that toxic substances may persist and accumulate in several echelons of the food chain leading eventually to humans is an example of the indirect, long-term implications of hazardous materials. There is also a growing concern that certain chemical wastes (e.g., some pesticides) may persist for periods of time that permit them to become entrained in the water cycle to reach surface or subsurface ground water and thus contaminate clean water supplies (References 9, 10, 11).

Better understanding and growing concern for all ecological populations comprising the total environment have introduced additional factors that must be considered in developing a list of hazardous substances. For example, substances which would not be directly damaging to particular plant or animal species may nevertheless produce deleterious effects on related forms of life which comprise their food supply or their preditor/competitor relationships. Thus, the balance of nature, achieved through long-term natural selection processes, can be upset and undesirable consequences result.

As substance or material may produce nontoxic effects from acute exposures (i.e., exposures of relatively large concentrations or doses over short time periods), but may produce serious effects from chronic exposures (i.e., exposures involving low concentration or dose levels over extended periods of time) (References 7, 9). Relatively good data have been obtained concerning acute exposures of humans as a result of reconstruction of industrial or other accident situations, but amounts and detail of such data are limited (Reference 12). Chronic exposure data on humans is more difficult to obtain because of the longer time periods involved and the difficulty of linking long-term deleterious effects definitively to a specific hazardous compound. Extrapolations from experimental animal data to estimates of human effects have been considered acceptable (with some reservations) for short-term acute or chronic exposures (i. e., days to, perhaps, weeks). But, longer-term animal exposures are not compatible with long-term human exposures and effects (i. e., order of years).

The difficulty of identifying hazardous waste substances is aggravated further by the wide spectrum of industrial and commercial activity that occurs. Consequently, waste effluents which may be discharged to the air, water, or the land, vary from municipal sewage and large amounts of ordinary household solid or liquid wastes to complex industrial mixtures containing an array of organic and inorganic compounds and drugs. The composition of these effluents cannot be predicted with certainty because of the variations of industrial production processes and the great diversity of products that are produced during any given period.

Thus, in partial summary, the analytical problems that evolve in developing a list of hazardous substances include the need for:

- Definitions of exposure concentration or dose levels and corresponding acute and chronic exposure effects

- Knowledge of subtle effects that occur, such as those caused by persistent toxic compounds

- Knowledge concerning the complex nature of effluent mixtures found in waste streams and in waste disposal processes

- Data on the complex composition and scheduling of industry which produces the wide spectrum of potentially hazardous products as well as by-products.

5. PREPARATION OF LIST OF HAZARDOUS MATERIALS

The basic list of hazardous substances, which was developed independently of the industrial sector analyses, evolved primarily from seven lists of hazardous materials which have been developed separately by interested government agencies or industrial associations. Pertinent information on derivation of each of the seven lists is provided in Table II-4. The reports themselves are included among the list of references (see References 6, 8, 13, 14, 16, 17, 18).

Each of the lists summarized in Table II-4 was prepared by a different organization. Each list includes a particular set of criteria which provides a hazard profile for each substance on the list. As evident in the table, the criteria are not consistent from list to list, but a substantial amount of information concerning hazardous effects and/or characteristics is provided for each substance or compound of each list. Where the same substance appears on several lists, the total amount of information made available is quite large and is useful for identification and relative rating of hazardous substances.

The preparation of each list of hazardous materials (Table II-4) by its authors could be considered as an effort to select and list those materials of particular impact on the mission of the publishing organization and thus includes some subjective judgments. The development of each list, however, represented a research and analysis effort involving masses of information and data which are worthy of incorporation into the current study. Accordingly, the lists were compared on an item by item basis to draw a basic list of a manageable number of substances. Only compounds found on two or more lists were included in an initial selection (see Appendix B for comparison of current, hazardous compounds lists). A further screening and reduction was desirable to reduce the list for ease of handling. This reduction was accomplished by introducing production amounts as an added criterion of relative hazard to the ecology and to the human population.

The matrix shown in Table II-5 presents the production criteria and the rationale for selecting compounds from other lists of hazardous material. These criteria were used for the second screening of the preliminary list of 900 hazardous substances. As a result of this screening, the initial list was reduced to approximately 400 chemical compounds.

Subsequently, additions were made to the basic list to bring its total to approximately 500 chemical substances or compounds.

These additions were made singly or by small groups. All were derived from study of the texts, reports, bulletins, etc., which were gathered during the information and data search phases of the study. For example, a series of 27 reports summarize 30 basic substances

Table II-4

Summary of Factors Included in Current Lists Of Hazardous Materials Developed By Government Agencies and Industrial Associations

Title and Agency (Date)	Number of Items In List (Approximate)	Focus of Attention	Criteria for Classification of Hazards	Remarks
Criteria for Selection of Elements and Compounds to be designated as Hazardous Polluting Substances E.P.A. Office of Water Programs, (1971)	400	Water Quality	Persistence Health Effects Ecological Effects Radioactive	Simple "Yes" to any one of five questions involving hazard criteria leads to classification as hazardous substance
Control of Spillage of Hazardous Polluting Substances for P.C.A., Department of Interior, (1970)	800	Water Quality	Health Effects Ecological Effects Aesthetic	Final Hazard rating and ranking based on production quantities, fractions shipped by various transport modes and historical probabilities of accident by each mode in addition to listed hazard criteria.
Dangerous Chemicals Code Los Angeles Fire Department	1900	Explosion and Fire Hazards (Air)	Explosive Range in Air Human Toxicity miscellaneous	Profiles only, based on listed hazard criteria for classification of hazards plus other parameters
Laboratory Waste Disposal Manual Manufacturing Chemists Assn. (1970)	1200	Air Quality and Air Hazards	Health Effects Fire Hazard Reactivity	Profile provided based on listed criteria for classification of hazards plus other parameters
Occupational Safety and Health Standards National Institute of Occupational Safety and Health (1971)	600	Air Quality	Human Health	List of threshold limit values for human exposures
Evaluation of the Hazard of Bulk Water Transportation of Industrial Chemicals National Academy of Sciences (1970)	200	Water Quality	Explosion, Health Effects, Ecological Effects, Aesthetics	Hazard evaluation system for bulk dangerous cargoes. Not applicable to other transport modes.
Chemical Safety References National Safety Council	500	Air and Water Quality	Varied - Health Effects Ecological Effects Explosion & Fire Reactivity	Flexible Format for presentations of information on list of substances. Composit of several other lists.

Table II-5
Criteria for Reduction of Preliminary List of Hazardous Substances

Production Levels	Number of Lists Substance Was Included On		
	1-2	3-4	5-7
Large $>1 \times 10^8$ lbs./yr.	Include	Include	Include
Medium $\geq 1 \times 10^7$ but $\leq 1 \times 10^8$ lbs./yr.	Omit	Include	Include
Small $>1 \times 10^7$ lbs./yr.	Omit	Omit	Include

and their compounds which have been identified as air pollutant hazards (see Bibliography). A number of metallic, organic and inorganic compounds, shown by experimental and accident data to be very toxic to humans, animals and plants, were added to the basic list of hazardous substances as a result of information contained in these reports. Similarly, several summary type reports have been prepared on pesticides as hazardous substances (References 10, 11, 21), and a number of pesticide compounds were added to the list based on information contained in these reports.

6. THE LIST OF HAZARDOUS COMPOUNDS AND ITS USES

The objective sought in the selection of compounds was to establish a comprehensive list rather than an exhaustive list of potentially hazardous materials. The list is representative of the toxic compounds which may require special waste management controls to minimize hazards to people and to the environment.

Such a list, then, represents materials which are likely to be hazardous if not properly controlled. Proper control of toxic materials can completely avoid hazardous exposures of people or the environment to such toxic effects. Only when proper management does not exist, or accidents occur in spite of precautions, do the potential hazards become real hazards.

The main utility of a comprehensive list of potentially hazardous materials is to identify the type and extent of the present and necessary management systems. Such systems might require development of special facilities to dispose of materials when such facilities are not readily available to consumers. They may also be used to identify the need for management controls in the production, shipment, storage and distribution systems of such materials as well as waste disposal problems. By and large, the producers of such materials maintain excellent controls which preclude hazardous conditions in the production processes. Less-skilled competency is available once these materials most into the commerce and consumer distribution systems.

The list of hazardous materials developed in this study is presented in Table II-6 along with the SIC codes identifying the basic producing and using industries, and the annual production figures, where available. The production figures given as "*10" indicate less than 10 million pounds total annual production. Certain hazardous materials of interest in Department of Defense and Atomic Energy Commission controlled activities are indicated in Chapter III-(page III-41 and Chapter IV (page IV-44 to IV-48).

Table II-6
List of Hazardous Materials

I D NUM	SUBSTANCE (COMMON) NAME	STANDARD INDUSTRIAL CODE MFR / USER	ANNUAL	PRODUCTION
1	ACETALDEHYDE	28	1652	MILLION LBS
2	ACETIC ACID	20, 28, 38	1770	MILLION LBS
3	ACETIC ANHYDRIDE	20, 26, 28, 36	1675	MILLION LBS
4	ACETONE	28, 38	1598	MILLION LBS
5	ACETONE CYANHYDRIN	28	970	MILLION LBS
6	ACETONITRILE (METHYL CYANIDE)	28	150	MILLION LBS
7	ACETYL CHLORIDE	20, 28	*10	MILLION LBS
8	ACETYLENE	28, 34	468	MILLION LBS
9	ACRIDINE	28	*10	MILLION LBS
10	ACROLEIN	19, 28	*10	MILLION LBS
11	ACRYLIC ACID	22, 26, 28, 31	150	MILLION LBS
12	ACRYLONITRILE	22, 28, 30	1037	MILLION LBS
13	ALDRIN	28	115	MILLION LBS
14	ALLYL ALCOHOL	19, 28	*10	MILLION LBS
15	ALLYL CHLORIDE	28	*10	MILLION LBS
16	ALUMINUM FLUORIDE	20, 28, 32, 33	286	MILLION LBS
17	ALUMINUM OXIDE	28, 32	*10	MILLION LBS
18	ALUMINUM SULFATE	20, 22, 26, 31, 49	2354	MILLION LBS
19	AMMONIA (AQUA-AMMONIUM HYDROXIDE)	28	26634	MILLION LBS
20	AMMONIUM CHLORIDE	20, 28, 36	450	MILLION LBS
21	AMMONIUM CHROMATE	22, 38	*100	MILLION LBS
22	AMMONIUM DICHROMATE	27, 28, 32, 38	*100	MILLION LBS
23	AMMONIUM FLUORIDE	20, 22, 24, 28, 32	*100	MILLION LBS
24	AMMONIUM NITRATE	28, 39	22400	MILLION LBS
25	AMMONIUM PERCHLORATE	28	200	MILLION LBS
26	AMMONIUM PERSULFATE	202 8,3 4,3 8	*100	MILLION LBS
27	AMMONIUM PICRATE (DRY)	28	*100	MILLION LBS
28	AMMONIUM PICRATE (WET)	28	*100	MILLION LBS
29	AMMONIUM SULFIDE	22, 33	100	MILLION LBS
30	AMYL ACETATE (BANANA OIL)	20, 22, 28, 39	*10	MILLION LBS
31	AMYL ALCOHOL (FUSEL OIL)	22, 28, 38	64	MILLION LBS
32	ANILINE	28, 30, 38	372	MILLION LBS
33	ANTHRACENES	28	100	MILLION LBS
34	ANTIMONY	22, 28, 30, 32, 33	72	MILLION LBS
35	ANTIMONY PENTACHLORIDE	28	*10	MILLION LBS
36	ANTIMONY PENTAFLUORIDE	28	*10	MILLION LBS
37	ANTIMONY PENTASULFIDE	28, 30, 39	*10	MILLION LBS
38	ANTIMONY POTASSIUM TARTRATE	28	*10	MILLION LBS
39	ANTIMONY SULFATE	28, 39	*10	MILLION LBS
40	ANTIMONY SULFIDE	28, 38, 39	*10	MILLION LBS
41	ANTIMONY TRIETHYL (TRIETHYLSTIBINE)	28	*10	MILLION LBS
42	ANTIMONY TRICHLORIDE	28, 33	*10	MILLION LBS
43	ANTIMONY TRIFLUORIDE	28, 32	*10	MILLION LBS
44	ANTIMONY TRIMETHYL (TRIMETHYLSTIBINE)	28	*10	MILLION LBS
45	ANTIMONY TRIOXIDE	28	14	MILLION LBS
46	ARSENIC	28	1040	MILLION LBS
47	ARSENIC CHLORIDE	28	*10	MILLION LBS
48	ARSENIC DIETHYL	28	*10	MILLION LBS
49	ARSENIC DIMETHYL	28	*10	MILLION LBS
50	ARSENIC PENTASELENIDE	32	*10	MILLION LBS

Table II-6
(Continued)

I D NUM	SUBSTANCE (COMMON) NAME	STANDARD INDUSTRIAL CODE MFR / USER	ANNUAL	PRODUCTION
51	ARSENIC TRICHLORIDE	28, 32	*10	MILLION LBS
52	ARSENIC TRIOXIDE	22, 28, 31, 32	*10	MILLION LBS
53	ASBESTOS PARTICLES	22, 28, 32	100	MILLION LBS
54	BARIUM CARBONATE	28, 32, 33	177	MILLION LBS
55	BARIUM CHLORIDE	28	*10	MILLION LBS
56	BARIUM CYANIDE	28, 34	*10	MILLION LBS
57	BARIUM FLUORIDE	28, 32, 36	*10	MILLION LBS
58	BARIUM NITRATE	28, 36, 39	*10	MILLION LBS
59	BARIUM SULFIDE	28, 30	*10	MILLION LBS
60	BENZENE	28	8000	MILLION LBS
61	BENZENE HEXACHLORIDE	28	100	MILLION LBS
62	BENZENE SULFONIC ACID	28	*10	MILLION LBS
63	BENZOIC ACID	28, 38	55	MILLION LBS
64	BENZYL CHLORIDE	28	88	MILLION LBS
65	BERYLLIUM CARBONATE	33	*10	MILLION LBS
66	BERYLLIUM CHLORIDE	28	*10	MILLION LBS
67	BERYLLIUM HYDROXIDE	28	*10	MILLION LBS
68	BERYLLIUM OXIDE	28, 32	*10	MILLION LBS
69	BERYLLIUM POWDER	33, 36	*10	MILLION LBS
70	BERYLLIUM SELENATE	28	*10	MILLION LBS
71	BORON TRICHLORIDE	28, 33	*10	MILLION LBS
72	BORON TRIFLUORIDE	28, 33	*10	MILLION LBS
73	BROMIC ACID	28	*10	MILLION LBS
74	BROMINE	28	362	MILLION LBS
75	BROMINE PENTAFLUORIDE	28	*10	MILLION LBS
76	BUTADIENE	28, 30	3054	MILLION LBS
77	BUTANE	28, 29	2160	MILLION LBS
78	BUTANOL (BUTYL ALCOHOL)	28	404	MILLION LBS
79	BUTENE - 1 (ETHYL ETHYLENE)	28	1630	MILLION LBS
80	BUTYLACETATE (BUTYL ETHANOATE)	22, 26, 28	127	MILLION LBS
81	BUTYLACRYLATE	28, 30	63	MILLION LBS
82	N-BUTYLAMINE	28	4	MILLION LBS
83	BUTYL MERCAPTAN	28	*10	MILLION LBS
84	BUTYL PHENOL	28	*10	MILLION LBS
85	BUTYRALDEHYDE (BUTYL ALDEHYDE - N)	28	*10	MILLION LBS
86	CACODYLIC ACID (DIMETHYLARSINIC ACID)	28	*10	MILLION LBS
87	CADMIUM	28, 34	11	MILLION LBS
88	CADMIUM CHLORIDE	22, 28, 32, 36, 38	*10	MILLION LBS
89	CADMIUM CYANIDE	34	*10	MILLION LBS
90	CADMIUM FLUORIDE	36	*10	MILLION LBS
91	CADMIUM NITRATE	28	*10	MILLION LBS
92	CADMIUM OXIDE	28, 30, 32, 33	*10	MILLION LBS
93	CADMIUM PHOSPHATE	28	*10	MILLION LBS
94	CADMIUM POTASSIUM CYANIDE	28	*10	MILLION LBS
95	CADMIUM SULFATE	28, 36	*10	MILLION LBS
96	CALCIUM ARSENATE	28	2.9	MILLION LBS
97	CALCIUM ARSENIDE	28, 33	*10	MILLION LBS
98	CALCIUM CARBIDE	22, 28	1580	MILLION LBS
99	CALCIUM CYANYDE	28	32	MILLION LBS
100	CALCIUM FLUORIDE	28, 32	2100	MILLION LBS

Table II-6
(Continued)

I D NUM	SUBSTANCE (COMMON) NAME	STANDARD INDUSTRIAL CODE MFR / USER	ANNUAL	PRODUCTION
101	CALCIUM HYDRIDE	28	*10	MILLION LBS
102	CALCIUM HYPOCHLORITE	28		MILLION LBS
103	CALCIUM OXIDE	28, 32	100	MILLION LBS
104	CARBON DISULFIDE	28	1640	MILLION LBS
105	CARBON MONOXIDE	20, 28, 33	100	MILLION LBS
106	CARBON TETRACHLORIDE	28	935	MILLION LBS
107	CARBON CHLORIDE (PHOSGENE)		447	MILLION LBS
108	CHLORAL HYDRATE	28	*10	MILLION LBS
109	CHLORINE	26, 28	28232	MILLION LBS
110	CHLORINE TRIFLUORIDE	28	*10	MILLION LBS
111	CHLOROACETOPHENONE	29	*10	MILLION LBS
112	CHLOROBENZENE (CHLOROBENZOL)	28	700	MILLION LBS
113	CHLOROPRENE	28	*10	MILLION LBS
114	CHLOROFORM (TRICHLOROMETHANE)	28	239	MILLION LBS
115	CHLOROSULFONIC ACID	28	154	MILLION LBS
116	CHROMIC ACID	28, 34	52	MILLION LBS
117	CHROMIC FLUORIDE	22, 28, 32, 34	*10	MILLION LBS
118	CHROMIC SULFATE	22, 28, 31, 32, 34	*10	MILLION LBS
119	CHROMIUM CYANIDE	28, 34	*10	MILLION LBS
120	COAL (PARTICLE)	29		MILLION LBS
121	COLBALT CHLORIDE	20, 28, 32, 38	*10	MILLION LBS
122	COBALTOUS NITRATE	28, 32	*10	MILLION LBS
123	COPPER ACETOARSENITE	24, 28	*10	MILLION LBS
124	COPPER CYANIDE (CUPROUS CYANIDE)	28	*10	MILLION LBS
125	COPPER NITRATE	28, 38	*10	MILLION LBS
126	COPPER SULFATE	28	94	MILLION LBS
127	CREOSOTE	24, 28	118	MILLION LBS
128	CRESOL (CRESYLIC ACID)	20, 28, 33	245	MILLION LBS
129	CROTONALDEHYDE	20, 28	*10	MILLION LBS
130	CUMENE (ISOPROPYLBENZOL)	28	1500	MILLION LBS
131	CYANIDES	28	*10	MILLION LBS
132	CYANOACETIC ACID	28	*10	MILLION LBS
133	CYCLOHEXANE (HEXAHYDROBENZENE)	28	280	MILLION GAL
134	CYCLOHEXANOL (HEXALIN)	28	716	MILLION LBS
135	CYCLOHEXANONE	28	704	MILLION LBS
136	CYCLOHEXYLAMINE	30	72	MILLION LBS
137	DEMETON	28		MILLION LBS
138	DECYL ALCOHOL	28	162	MILLION LBS
139	DIBUTYL PATHALATE - N	28	29	MILLION LBS
140	O - DICHLOROBENZENE	28	75	MILLION LBS
141	P - DICHLOROBENZENE	28	72	MILLION LBS
142	2,4-DICHLOROPHENOXYACETIC ACID (2,4-D)	28	368	MILLION LBS
143	DDD (DICHLORO DIPHENYL DICHLORO ETHENE)	28		MILLION LBS
144	DDT (DICHLORO DIPHONYL-TRICHLOROETHANE)	28	70	MILLION LBS
145	DIBORANE (BORON HYDRIDE)	28		MILLION LBS
146	DICHLOROETHYL ETHER	28		MILLION LBS
147	DICHLOROMETHANE (METHYLENE CHLORIDE)	28	418	MILLION LBS
148	1, 2 - DICHLOROPROPANE	28	86	MILLION LBS
149	1, 3 - DICHLOROPROPENE	28		MILLION LBS
150	DIELDRIN	28		MILLION LBS

Table II-6
(Continued)

I D NUM	SUBSTANCE (COMMON) NAME	STANDARD INDUSTRIAL CODE MFR / USER	ANNUAL	PRODUCTION
151	DIETHANOLAMINE	28	92	MILLION LBS
152	DIETHYLAMINE	28. 29. 30	7	MILLION LBS
153	DIETHYL ETHER (ETHYL ETHER)	28	102	MILLION LBS
154	DIETHYLENE DIOXIDE (1. 4 - DIOXANE)	28		MILLION LBS
155	DIETHYLENE TRIAMINE	28		MILLION LBS
156	DIETHYLSTILBESTROL	28		MILLION LBS
157	DIISOBUTYLENE	28	32	MILLION LBS
158	DIISOBUTYL KETONE	28		MILLION LBS
159	DIMETHYLAMINE	28	74	MILLION LBS
160	DIMETHYL SULFATE (METHYL SULFATE)	26. 26. 29		MILLION LBS
161	2. 4 - DINITROANILINE	28. 34	222	MILLION LBS
162	DINITRO - O - CRESOLS	28. 29		MILLION LBS
163	O-DINITROBENZOL (1.2-DINITROBENZENE)	28		MILLION LBS
164	2. 4 - DINITROPHENOL	28. 34	.9	MILLION LBS
165	2. 4 - DINITROTOLUENE (DINITROTOLUOL)	28	259	MILLION LBS
166	DIPHENYLAMINE (PHENYLANILINE)	28	35	MILLION LBS
167	DIPROPYLENE GLYCOL	28	45	MILLION LBS
168	DODECYL BENZENE (CRUDE)	28	533	MILLION LBS
169	ENDRIN	28		MILLION LBS
170	EPICHLOROHYDRIN	20. 28	120	MILLION LBS
171	ETHANE	28		MILLION LBS
172	ETHANOL (ETHYL ALCOHOL)	20. 28	320	MILLION GAL
173	ETHANOLAMINE (MONOETHANOLAMINE)	22. 28. 29	265	MILLION LBS
174	ETHERS	28		MILLION LBS
175	ETHYL ACETATE (ACETIC ETHER)	28	159	MILLION LBS
176	ETHYL ACRYLATE	22. 26. 28. 31	167	MILLION LBS
177	ETHYLAMINE (MONOETHYLAMINE)	20. 28	16	MILLION LBS
178	ETHYL BENZENE (PHENYL ETHANE)	28	4700	MILLION LBS
179	ETHYL CHLORIDE (CHLOROETHANE)	28	600	MILLION LBS
180	ETHYLENE (ETHENE)	28	15600	MILLION LBS
181	ETHYLENE BROMIDE (ETHYLENE DIBROMIDE)	28. 29		MILLION LBS
182	ETHYLENE CYANOHYDRIN	28		MILLION LBS
183	ETHYLENE DIAMINE	28	65	MILLION LBS
184	ETHYLENE DIBROMIDE (DIBROMOETHANE)	28		MILLION LBS
185	ETHYLENE DICHLORIDE (1.2-DICHLOROETHANE)	28	6700	MILLION LBS
186	ETHYLENE GLYCOL (GLYCOL)	28	2400	MILLION LBS
187	ETHYLENE GLYCOL MONOETHYL ETHER	28		MILLION LBS
188	ETHYLENE GLYCOL MONOETHYL ETHER ACETATE	28		MILLION LBS
189	ETHYLENE OXIDE	28	3671	MILLION LBS
190	ETHYLENIMINE	22. 26. 28. 34	1.5	MILLION LBS
191	2-ETHYLHEXANOL (OCTYL ALCOHOL)	28	440	MILLION LBS
192	ETHYL MERCAPTAN	28		MILLION LBS
193	ETHYL METHYL KETONE (BUTANONE)	28		MILLION LBS
194	ETHYL PHTHALATE (DIETHYL O-PHTHALATE)	28		MILLION LBS
195	2-ETHYL - 3 PROPYL ACROLEIN	28		MILLION LBS
196	FERROUS SULFATE	20. 28	340	MILLION LBS
197	FLUORIDES (E.G..HYDROGEN FLUORIDE.ETC.)	28		MILLION LBS
198	FLUORINE (HYDROFLUORIC ACID)	28	1400	MILLION LBS
199	FORMALDEHYDE - 37 PERCENT SOLUTION	20. 22. 28. 39. 73	4312	MILLION LBS
200	FORMIC ACID	22. 28. 31	40	MILLION LBS

Table II-6
(Continued)

I D NUM	SUBSTANCE (COMMON) NAME	STANDARD INDUSTRIAL CODE MFR / USER	ANNUAL	PRODUCTION
201	FURFURAL (FURFURALDEHYDE)	28	380	MILLION LBS
202	FURFURAL ALCOHOL	28	22	MILLION LBS
203	GUTHION	28		MILLION LBS
204	HEPTALCHOR	28		MILLION LBS
205	HEPTANE (HEPTYL HYDRIDE)	28	244	MILLION LBS
206	HEXACHLOROPHENE (METHYLENE)	28		MILLION LBS
207	HEXAETHYLTETRAPHOSPHATE	34, 38		MILLION LBS
208	HEXAMETHYLENE DIAMINE	28, 34		MILLION LBS
209	HEXANE (HEXYL HYDRIDE)	28	232	MILLION LBS
210	HYDRAZINE (ANHYDROUS DIAMINE)	28		MILLION LBS
211	HYDROBROMIC ACID	28		MILLION LBS
212	HYDROCHLORIC ACID (MURIATIC ACID)	20, 28, 33, 35	8122	MILLION LBS
213	HYDROCYANIC ACID (HYDROGEN CYANIDE)	28, 33, 34	410	MILLION LBS
214	HYDROFLUORIC ACID (HYDROGEN FLUORIDE)	28, 29, 33, 34	629	MILLION LBS
215	HYDROGEN CHLORIDE ANHYDROUS	28		MILLION LBS
216	HYDROGEN PEROXIDE (OVER 52 PERCENT	22, 26, 28	132	MILLION LBS
217	P - HYDROQUINONE	28, 34	12	MILLION LBS
218	HYDROGEN SULFIDE	28, 33	1280	MILLION LBS
219	IODINE	28		MILLION LBS
220	ISOBUTYL ACETATE	28, 34		MILLION LBS
221	ISOBUTYL ALCOHOL	28		MILLION LBS
222	ISOPHORONE	28		MILLION LBS
223	ISOPRENE	28, 30	260	MILLION LBS
224	ISOPROPANOL (ISOPROPYL ALCOHOL)	28	2000	MILLION LBS
225	ISOPROPYL ACETATE	28	44	MILLION LBS
226	ISOPROPYL AMINE	28	20	MILLION LBS
227	ISOPROPYL ETHER	22, 28	12	MILLION LBS
228	LEAD	28, 29, 33, 35, 36	2657	MILLION LBS
229	LEAD ACETATE	28, 31		MILLION LBS
230	LEAD ARSENATE	28	12	MILLION LBS
231	LEAD ARSENITE	28		MILLION LBS
232	LEAD CARBONATE	28		MILLION LBS
233	LEAD CHLORITE	18		MILLION LBS
234	LEAD CYANIDES	28, 33		MILLION LBS
235	LEAD NITRATE	28, 34, 39		MILLION LBS
236	LEAD NITRITE	28		MILLION LBS
237	LEAD OXIDE	28, 30, 32		MILLION LBS
238	LITHIUM ALUMINUM HYDRIDE	28		MILLION LBS
239	MAGNESIUMO-ARSENITE	28		MILLION LBS
240	MAGNESIUM CHLORATE	28		MILLION LBS
241	MAGNESIUM SULFATE	22, 26, 28, 31, 32, 36		MILLION LBS
242	MALEIC ANHYDRIDE	28	216	MILLION LBS
243	MANGANESE	28, 34		MILLION LBS
244	MANGANESE ARSENATE	28		MILLION LBS
245	MANGANESE CHLORIDE	22, 28, 35, 36		MILLION LBS
246	MANGANESE CYCLOPENTADIENYLTRICARBONYL	28		MILLION LBS
247	MERCURIC CHLORIDE	24, 28, 31, 33, 34, 38		MILLION LBS
248	MERCURIC CYANIDE	28, 38		MILLION LBS
249	MERCURIC DIAMMONIUM CHLORIDE	28		MILLION LBS
250	MERCURIC NITRATE	28		MILLION LBS

Table II-6
(Continued)

I D NUM	SUBSTANCE (COMMON) NAME	STANDARD INDUSTRIAL CODE MFR / USER	ANNUAL	PRODUCTION
251	MERCURIC SULFATE	28, 33, 36		MILLION LBS
252	MERCURY	26, 28, 36	.5	MILLION LBS
253	MERCURY COMPOUNDS (ORGANIC)	28		MILLION LBS
254	MESITYL OXIDE	28		MILLION LBS
255	METHANOL (METHYL ALCOHOL)	28, 29	9245	MILLION LBS
256	METHYL ACETATE	28	9	MILLION LBS
257	METHYL ACRYLATE (ACRYLIC ESTERS)	28, 31		MILLION LBS
258	METHYLAMINE (30 PERCENT SOLUTION)	28, 30	120	MILLION LBS
259	METHYL AMYL ALCOHOL	29		MILLION LBS
260	METHYL BROMIDE (BROMOMETHANE)	28	21	MILLION LBS
261	METHYL CHLORIDE (CHLOROMETHANE)	28, 30	432	MILLION LBS
262	METHYL CHLOROFORMATE	28		MILLION LBS
263	METHYL FORMATE (METHYL METHANOATE)	26		MILLION LBS
264	METHYL ISOBUTYL KETONE (HEXONE)	28		MILLION LBS
265	METHYL MERCAPTANS (METHANETHIOL)	29		MILLION LBS
266	METHYL METHACRYLATE MONOMER	28, 29	430	MILLION LBS
267	METHYL PARATHION	28	51	MILLION LBS
268	MONOMETHYLANILINE (N-METHYLANILINS)	28		MILLION LBS
269	MORPHOLINE	28, 30, 34	21	MILLION LBS
270	NAPHTHA (CRUDE)	28	1420	MILLION LBS
271	NAPHTHALENE (NAPHTHALINE)	28, 31, 34	700	MILLION LBS
272	NAPHTHYLAMINE - BETA	28		MILLION LBS
273	NICKEL	28, 33, 34	30	MILLION LBS
274	NICKEL AMMONIUM SULFATE	28, 34		MILLION LBS
275	NICKEL ANTIMONIDE	28, 34		MILLION LBS
276	NICKEL ARSENIDE	32		MILLION LBS
277	NICKEL CARBONYL	28		MILLION LBS
278	NICKEL CHLORIDE	28, 34		MILLION LBS
279	NICKEL CYANIDE	33, 34		MILLION LBS
280	NICKEL NITRATE	28, 32, 34		MILLION LBS
281	NICKEL SELENIDE	36		MILLION LBS
282	NICKEL SULFATE	28	40	MILLION LBS
283	NITRIC ACID	27, 28, 33, 34	6887	MILLION LBS
284	NITROANILENE (NITRANELINE-META-PARA)	28	10	MILLION LBS
285	NITROBENZENE (NITROBENZOL)	28	515	MILLION LBS
286	NITROCHLOROBENZINE (META OR PARA)	28, 30	100	MILLION LBS
287	NITROETHANE	28		MILLION LBS
288	NITROGLYCERIN	19, 28		MILLION LBS
289	NITROMETHANE	29		MILLION LBS
290	NITROPARAFFINS	19, 28		MILLION LBS
291	P - NITROPHENOL	28, 34	50	MILLION LBS
292	NITROPROPANE (1 AND 2)	28		MILLION LBS
293	P - NITROTOLUOL (NITROTOLUENE)	19, 28, 34	18	MILLION LBS
294	NITROUS OXIDE	20, 28	951	MILLION GAL
295	OXALIC ACID	22, 28, 31	23	MILLION LBS
296	PARAFORMALDEHYDE	28		MILLION LBS
297	PARATHION	28		MILLION LBS
298	PENTABORANE	28		MILLION LBS
299	PENTACHLOROPHENOL	22, 24, 26, 28	47	MILLION LBS
300	PETN (PENTAERYTHRITOL TETRANITRATE)	19, 28	5	MILLION LBS

Table II-6
(Continued)

I D NUM	SUBSTANCE (COMMON) NAME	STANDARD INDUSTRIAL CODE MFR / USER	ANNUAL	PRODUCTION
301	N - PENTANE (AMYL HYDRIDE)	28. 38		MILLION LBS
302	PERCHLORIC ACID (S 72 PERCENT)	28		MILLION LBS
303	PERCHLOROETHYLENE (TETRACHLOROETHYLENE)	22. 28	706	MILLION LBS
304	PERCHLORYL FLUORIDE	28		MILLION LBS
305	PHENOL (CARBOLIC ACID)	28	1680	MILLION LBS
306	PHENYLHYDROGINE HYDROCHLORIDE	28		MILLION LBS
307	PHOSPHORIC ACID	20. 28. 34. 38	5	MILLION LBS
308	PHOSPHORUS (RED)	22. 28		MILLION LBS
309	PHOSPHORUS (WHITE OR YELLOW)	19. 28	1220	MILLION LBS
310	PHOSPHORUS OXYCHLORIDE	28. 29	65	MILLION LBS
311	PHOSPHORUS PENTACHLORIDE	28		MILLION LBS
312	PHOSPHORUS PENTASULFIDE	28. 29	94	MILLION LBS
313	PHOSPHORUS TRICHLORIDE	28. 33		MILLION LBS
314	PHTHALIC ACID (TEREPHTHALIC ACID)	28	760	MILLION LBS
315	PICRIC ACID (TRINETROPHENOL)	19. 28		MILLION LBS
316	POLYCHLORINATED BIPHENYLS (ASKARELS)	36		MILLION LBS
317	POTASSIUM ARSENITE	28. 32		MILLION LBS
318	POTASSIUM BINOXALATE	28. 34		MILLION LBS
319	POTASSIUM CHROMATE	28		MILLION LBS
320	POTASSIUM CYANIDE (SOLID)	10. 28. 33. 34		MILLION LBS
321	POTASSIUM DICHROMATE	22. 26. 27. 28. 29. 31		MILLION LBS
322	POTASSIUM FLUORIDE	20. 28. 32		MILLION LBS
323	POTASSIUM HYDROXIDE (CAUSTIC POTASH)	28	360	MILLION LBS
324	POTASSIUM OXALATE	28. 34		MILLION LBS
325	POTASSIUM PERMANGANATE	22. 28. 31. 38		MILLION LBS
326	POTASSIUM PEROXIDE	28		MILLION LBS
327	POTASSIUM SULFATE	28	544	MILLION LBS
328	POTASSIUM SULFIDE	28. 30. 33. 34. 35. 39		MILLION LBS
329	PROPANE (L.P. GAS)	28. 29	7200	MILLION LBS
330	PROPIONALDEHYDE (PROPYL ALDEHYDE)	28. 30. 32		MILLION LBS
331	PROPIONIC ACID	28	40	MILLION LBS
332	N - PROPYL ACETATE	20. 28	21	MILLION LBS
333	N - PROPYL ALCOHOL	28	58	MILLION LBS
334	PROPYLAMINE	28	.2	MILLION LBS
335	PROPYLENE	28. 29	7240	MILLION LBS
336	PROPYLENE GLYCOL	28	450	MILLION LBS
337	PROPYLENE OXIDE	28	1121	MILLION LBS
338	PROPYLENE DICHLORIDE (DICHLOROPROPANE)	20. 28		MILLION LBS
339	PYRIDINE	28. 30	7	MILLION LBS
340	QUINONE	28. 34		MILLION LBS
341	SALICYLIC ACID	28. 30	44	MILLION LBS
342	SELENIUM POWDER	319 .30 .32 .33 .36	.6	MILLION LBS
343	SILICON TETRACHLORIDE	19. 28		MILLION LBS
344	SILVER CYANIDES	34	.1	MILLION LBS
345	SODIUM	28. 33	314	MILLION LBS
346	SODIUM AMIDE (SODAMIDE)	28		MILLION LBS
347	SODIUM ARSENATE	22. 28		MILLION LBS
348	SODIUM ARSENITE	28		MILLION LBS
349	SODIUM AZIDE	19. 28		MILLION LBS
350	SODIUM BICHROMATE (SODIUM DICROMATE)	28	299	MILLION LBS

Table II-6
(Continued)

I D NUM	SUBSTANCE (COMMON) NAME	STANDARD INDUSTRIAL CODE MFR / USER	ANNUAL	PRODUCTION
351	SODIUM BISULFITE	20. 26. 28		MILLION LBS
352	SODIUM BORATE	28. 32. 33	1248	MILLION LBS
353	SODIUM CACODYLATE	28		MILLION LBS
354	SODIUM CARBONATE	26. 28. 32	1340	MILLION LBS
355	SODIUM CARBONATE PEROXIDE	26. 28		MILLION LBS
356	SODIUM CHLORATE	26. 28	374	MILLION LBS
357	SODIUM CHROMATE	28		MILLION LBS
358	SODIUM CYANIDE	28	13	MILLION LBS
359	SODIUM FLUORIDE	28	13	MILLION LBS
360	SODIUM FORMATE	28		MILLION LBS
361	SODIUM HYDRIDE (CRYSTALS)	28		MILLION LBS
362	SODIUM HYDROSULFITE	22. 28	79	MILLION LBS
363	SODIUM HYDROXIDE (CAUSTIC SODA)	20. 22. 26. 28. 29	21000	MILLION LBS
364	SODIUM IODIDE	28		MILLION LBS
365	SODIUM NITRATE (SOLID)	28	783	MILLION LBS
366	SODIUM NITRITE (SOLID)	20. 28. 33. 34		MILLION LBS
367	SODIUM OXALATE	28		MILLION LBS
368	SODIUM OXIDE	28		MILLION LBS
369	SODIUM PERCHLORATE	19		MILLION LBS
370	SODIUM PEROXIDE	28		MILLION LBS
371	SODIUM PHOSPHATE	28. 32. 35	2900	MILLION LBS
372	SODIUM POTASSIUM ALLOY	28		MILLION LBS
373	SODIUM SULFIDE	28. 30. 33. 34. 35. 39	203	MILLION LBS
374	SODIUM SULFITE	28	452	MILLION LBS
375	SODIUM THIOCYANATE (SODIUM SULFOCYANIDE)	28		MILLION LBS
376	STANNIC CHLORIDE	28		MILLION LBS
377	STANNOUS CHLORIDE	28		MILLION LBS
378	STRONTIUM	28. 29. 32	26	MILLION LBS
379	STYRENE (PHENYL ETHYLENE)	26. 28	4400	MILLION LBS
380	SULFURE DIOXIDE	20. 26. 28. 29. 33	256	MILLION LBS
381	SULFUR TRIOXIDE	19. 28		MILLION LBS
382	SULFURIC ACID	26. 28. 33. 34. 35	59077	MILLION LBS
383	SULFUROUS ACID	28		MILLION LBS
384	SULFURYL FLUORIDE	28		MILLION LBS
385	TANTALUM	28. 33		MILLION LBS
386	TAR (LIQUID)	29	769	MILLION LBS
387	TEAR GAS (CN)	19		MILLION LBS
388	TETRACHLOROETHANE(ACETYLENETETRACHLORIDE	28		MILLION LBS
389	TETRAETHYL LEAD	29	371	MILLION LBS
390	TETRAHYDROFURAN	28		MILLION LBS
391	TETRAMETHYL LEAD	29	76	MILLION LBS
392	TETRANITROMETHANE	19		MILLION LBS
393	THALLIUM	28. 33. 34		MILLION LBS
394	THALLIUM SULFATE	28		MILLION LBS
395	TITANIUM TETRACHLORIDE	28		MILLION LBS
396	TOLUENE (TOLYOL)	19. 28. 29	5380	MILLION LBS
397	TOLUENE DISOCYANATE	28. 29		MILLION LBS
398	TOLUIDINE - O (2.4 -METHYLANILENE)	22. 28	9	MILLION LBS
399	TRICHLOROBENZENE	28	15	MILLION LBS
400	TRICHLOROETHANE (A OR B)	22. 28. 33. 34	340	MILLION LBS

Table II-6
(Continued)

I D NUM	SUBSTANCE (COMMON) NAME	STANDARD INDUSTRIAL CODE MFR / USER	ANNUAL	PRODUCTION
401	TRICHLOROETHYLENE	22, 28, 34	630	MILLION LBS
402	TRICHLOROFLUOROMETHANE (FREON 11)	28	239	MILLION LBS
403	TRIETHANOLAMINE	28, 32	77	MILLION LBS
404	TRIETHYLAMINE	28		MILLION LBS
405	TRIETHYLENE GLYCOL	28, 29	80	MILLION LBS
406	TRIETHYLENE TETRAMINE	28		MILLION LBS
407	TRIMETHYLAMINE	28	20	MILLION LBS
408	TRI-O-CRESYL PHOSPHATE	28, 29, 35	48	MILLION LBS
409	TURPENTINE	28	31	MILLION GAL
410	VANADIUM PENTOXIDE	22, 28, 32, 38		MILLION LBS
411	VANADIUM SULFIDE	28, 32		MILLION LBS
412	VINYL ACETATE	28	799	MILLION LBS
413	VINYL CHLORIDE	28, 30, 34	4040	MILLION LBS
414	M - XYLENE (XYLOX)	28		MILLION LBS
415	XYLENOL (3, 5-DIMETHYLPHENOL)	28	15	MILLION LBS
416	ZINC ARSENATE	28		MILLION LBS
417	ZINC ARSENITE	28		MILLION LBS
418	ZINC CHLORIDE	28, 30, 33, 36	106	MILLION LBS
419	ZINC CYANIDE	28, 34, 35		MILLION LBS
420	ZINC NITRATE	22, 28		MILLION LBS
421	ZINC OXIDE	20, 22, 28, 30, 32, 34	420	MILLION LBS
422	ZINC PERMANGANATE	28		MILLION LBS
423	ZINC PEROXIDE	28		MILLION LBS
424	ZINC SULFIDE	28, 36	1	MILLION LBS

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III. QUANTIFICATION OF HAZARDOUS WASTES

1. INTRODUCTION

This chapter presents estimates of the amounts of wastes produced in the various industrial sectors and limited geographic locations. Estimates have been made necessary because of the nearly complete lack of data describing waste quantities in the literature. With the exception of radioactive waste data available from Atomic Energy Commission reports, the literature is silent on the subject of hazardous waste quantities. The reasons for this situation are many, but principal among them are:

- Historically, there has been no interest or objective in quantifying waste amounts of specific materials, with the exception of radioactive wastes, which are subject to a stringent control system.
- For certain materials, such as pesticides and herbicides, the utilization and disposal cycles were one and the same, but geographic location data were not recorded.
- In nearly all waste disposal processes, whether industrial, governmental, or domestic, materials being wasted are thrown together and become streams of mixed wastes.
- Predisposal treatment, where employed at all, has been applied to a limited number of waste stream characteristics, rather than to characteristics of specific materials.

The impact of the latter two factors above on the hazardous waste quantification problem cannot be overstated. The difficulties imposed can be made more apparent when it is noted that mixed waste streams:

- Can have hazardous materials as inputs
- Are not analyzed in detail, if at all

- Might be chemically indeterminate, as a result of unknown reactions
- Might exhibit some, all, or none of the characteristics of individual input materials
- Might become hazardous through combinations of non-hazardous input materials.

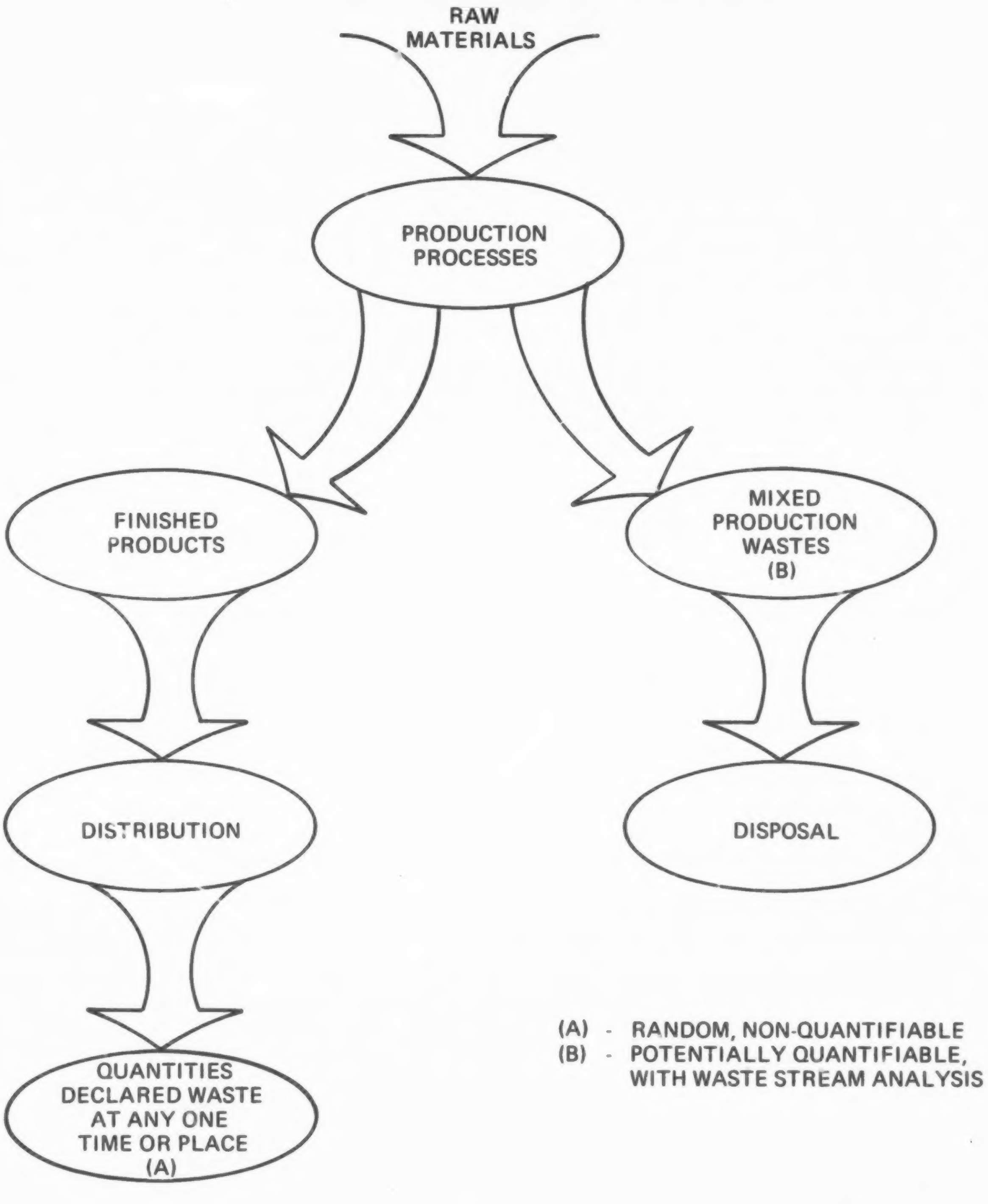
Investigation of the overall problem of quantifying waste hazardous materials has to consider the problem of disposing of such materials in their pure (or relatively pure) form, as well as in waste streams. Many of these materials are created as (or in) marketable products not meant to be wasted, yet for various reasons (shelf-life, contamination, etc.) at some time become wastes. In such cases, someone has to declare them no longer needed and thus ready for disposal. This waste quantification problem is compared to the mixed waste quantification problem in Figure III-1.

The result is that in order to present waste quantity estimates, it has also been necessary in this study to develop calculation methods for estimating purposes. Most of the calculations that have been made are based on waste generation as a function of production (e.g., pounds of waste per thousand pounds of production). In some cases, these general waste quantification factors appeared in the literature. When such factors were not obtainable in literature references, values were calculated from the best available data. Derivation of these factors for industries which are relatively homogenous (e.g., textiles) provides a reasonable factor estimate for the industry as a whole. Other industries are so diverse that derivation of general quantification factors for the industry is unrealistic. This is especially true of the chemical industry, with its great diversity (many thousands of processes, products, and their combinations). The chemical industry factors were separately derived from results of a 1967 survey conducted by the Manufacturing Chemists Association.

The waste quantification data is presented in three ways:

- Total wasteloads of various industries in each of the 50 largest Standard Metropolitan Statistical Areas (SMSA) and in each of the 50 states

FIGURE I-1
The Hazardous Materials
Waste Quantification Problem


RAW MATERIALS
PRODUCTION PROCESSES
FINISHED PRODUCTS
MIXED PRODUCTION WASTES (B)
DISTRIBUTION
DISPOSAL
QUANTITIES DECLARED WASTE AT ANY ONE TIME OR PLACE (A)
(A) - RANDOM, NON-QUANTIFIABLE
(B) - POTENTIALLY QUANTIFIABLE, WITH WASTE STREAM ANALYSIS

- Estimates of commonly-known mixed, potentially hazardous, waste streams generated by various industries, with breakdowns of specific hazardous materials, where such data is available
- Reported quantities of hazardous and potentially hazardous wastes from the Department of Defense, Atomic Energy Commission, and the mining industry.

It must be borne in mind that these discussions and the quantity estimating methods are generalized, referring to entire industries. In some industries, the production processes and materials used change frequently, so general estimating methods produce results that are only indicators rather than facts, and should be utilized in that light. Further, the methods and results cannot be extrapolated to individual plants, since all plants in an industry do not produce the same products, nor do they all utilize the same processes. This is mitigated to some extent in the relatively homogenous industries, but in any case, caution is the byword in application of these data.

2. PRODUCTION QUANTITIES OF HAZARDOUS MATERIALS

The data which has been developed provides limited information as to the number of pounds of specific hazardous waste compounds which are produced in each geographic area. Such information may be impossible to produce completely, since it involves, at minimum: consideration of great numbers of water waste streams whose toxicity or other hazards might not be related to specific compounds, product wastes from a wide variety of industrial and consumer sources, toxic substances which have become intermingled with solid waste trash and municipal sewage, and finally, no knowledge as to whether threshold concentrations had been reached or if susceptible populations were present.

The best estimation of the total amount of any particular compound is, of course, the amount produced. Determinations as to the amounts which will enter waste streams must be made for each compound. Many are converted to nontoxic compounds. Others are neutralized. Still others may remain toxic and be widely distributed intentionally (pesticides), while residual amounts of many compounds may enter few or many municipal waste streams. Only specific life-cycle studies which are made compound by compound for, say, 10-15 compounds initially, will provide accurate distribution patterns and reasonable estimates of the geographic distribution of residual quantities. Where production data are available, they have been included in the hazardous material listing in Chapter II (Table II-6, page II-29), developed from the punched-card data records developed during this study.

3. TOTAL WASTELOAD ESTIMATES

Utilizing the general waste quantification factors, data indicating total wasteloads of various industries have been computed for those industries in the 50 largest SMSAs, accounting for about 60 percent of industrial production, and for the 50 states, accounting for all domestic production. Initially, it was planned to develop the data for each of the nation's 230 SMSAs, but it was discovered that many chemical plants and other production facilities are located outside such metropolitan areas. These conditions apply particularly to the smaller SMSAs.

The value added in manufacture was the scaling factor used to convert ratios of pounds of waste to pounds of product, to pounds of waste by industry by SMSA or by state. This was done by first relating the production output to the value added and then by relating the pounds of waste/1000 pounds of product to the production-value-added ratios.

The quantity estimates which have been prepared in this manner provide estimates as to the relative amounts of waste which are produced in each geographic area. They are most accurate in depicting the relative amounts produced in each geographic area. They are likely to be most inaccurate if used to predict the waste output from a single facility.

The difficulties in arriving at accurate estimates for use in projecting gross quantities are manifold. A graphic display of the results of these difficulties is shown in Table III-1, which compares predictions made by two separate studies, one by Combustion Engineering for the Solid Waste Management Office and the other by the California Department of Public Health. These two studies separately estimated solid waste quantities for all the manufacturing industries. The vast differences between results of the two studies, demonstrate the lack of consistent quantitative data.

Table III-1
Comparison of Solid Waste Estimates

SIC Industry	Waste in Million Pounds per Year (Total U. S.)	
	Combustion Engineering Study (1)	California Study (2)
19 Ordnance and Accessories	711	NA
20 Food and Kindred Products	14,260	43,880
21 Tobacco Manufacture	813	—
22 Textile Mill Products	2,158	340
23 Apparel and Textile Products	719	650
24 Lumber and Wood Products	76,107	137,660
25 Furniture and Fixtures	3,877	430
26 Paper and Allied Products	10,189	2,550
27 Printing and Publishing	15,221	1,030
28 Chemicals and Allied Products	6,048	5,050
29 Petroleum and Coal Products	1,148	5,800
30 Rubber and Plastics Products	4,927	2,690
31 Leather and Leather Products	6,325	—
32 Stone, Clay and Glass Products	4,915	2,830
33 Primary Metal Industries	3,503	9,800
34 Fabricated Metal Products	7,660	3,300
35 Machinery, Except Electrical		8,400
36 Electrical Equipment and Supplies	3,047	4,640
37 Transportation Equipment	3,479	3,080
38 Instruments and Related Products	1,665	—
39 Miscellaneous Manufacturing	1,696	—

(1) Technical-Economic Study of Solid Waste Disposal Needs and Practices, Volume II, Industrial Inventory, Combustion Engineering, Inc., for the U.S. Department of Health, Education and Welfare, Public Health Service, Clearinghouse for Federal Scientific and Technical Information, Pub. 1886, Report SW-7c, Pub. PB-187-712, 1969.

(2) California Solid Waste Planning Study, California Department of Public Health, 1969.

The area waste generation calculations are augmented by data of various types which relate to specific compounds. These data are contained in the Appendices (Volumes II and III) describing the various industries, which provide a single source of information for useful data compiled from a variety of sources.

Two basic parameters were developed to estimate the quantity of waste material produced in each industrial sector. The first is an estimate of pounds of waste produced per thousand pounds of product, or an equivalent ratio. The second is the value added by the manufacture of an equivalent amount of production.

(1) Value Added as a Measure of Production

Value added by manufacture is derived by subtracting the total cost of materials, (including materials, supplies, fuel, electric energy, cost of resales and miscellaneous receipts), from the value of shipments (including resales) and other receipts, and adjusting the resulting amount by the net change in finished products and work-in-process inventories between the beginning and end of the year. The value of shipment is net selling value, f. o. b. plant, after discounts and allowances and excluding freight charges and excise tax.

The value added factor is considered by the Department of Commerce to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas. The value added figure provides the measure for industrial activity and for indices of industrial production, productivity, and price, all of which are essential for estimating industrial waste production.

The other measures, such as number of employees and value shipped, have been used by other studies. These measures have some inherent flaws which make value added the desired factor. The number of employees factor cannot be applied to seasonal industries because the number of employees data is collected for one given period and does not consider changes in employment during the year. The value added figure also avoids duplication in the value of shipments figure, which results from the inclusion of the shipments of establishments producing materials and components, along with the shipments of establishments producing finished products.

(2) Waste Production Factors

Waste production factors are multipliers which can be applied to production data of a particular industry in a given geographic location for estimating waste quantity. As pointed out earlier, the value added has been considered a good measure of production. Therefore, the waste production factors have been developed such that they can be directly multiplied by the value added figure for any given industry to determine the amount of waste produced by the industry.

The major products and the manufacturing processes of the selected industries were studied and are reported in Appendix A. The literature study of these industries resulted in derivation of values indicating amount of waste generated per 1,000 pounds of product (WPPP). The WPPP values for the selected industries are listed in Column (2) of Table III-2, and their data sources are listed in Column (5). To derive waste factors, the WPPP for each industry was divided by the dollar value added per thousand pounds of product (VAPP) listed in Column (3). Waste factors are given in Column (4). Thus:

$$\frac{\text{WPPP}}{\text{VAPP}} = \frac{\text{lb. waste/1,000 lb. product}}{\text{\$ value added/1,000 lb. product}} = \frac{\text{pounds waste}}{\text{\$}}$$

and:

$$\frac{\text{Pounds waste}}{\text{\$}} \times \text{Total \$ value added} = \text{Total lb. waste.}$$

This method for computing the waste factors was not used for the chemical industry. The waste streams from the various types of chemical plants differ extensively because of the great variety of products which are produced. Instead, data from the 1967 survey of members of the Manufacturing Chemists Association (MCA) was used. This survey showed the amount of waste produced by the plants, which were surveyed in each state, and the total employees in these plants. From this information, the total annual waste produced per employee was computed for each state. The data used for this calculation were based on the "estimated amount of waste if no treatment or control measures were in use." Therefore, the waste quantities are the totals produced by the industry, and are more than the amount of waste discharged to the environment. According to

Table III-2
Computation of Waste Factors

SIC Industry Col. (1)	WPPP Waste (lbs) per 1000 lbs. of Product Col. (2)	VAPP Value ($) Added per 1000 lbs. of Product Col. (3)	WPPP/VAPP (#/$) Waste Factor Col. (4)	Data Source Col. (5)
20 Food Industry	NA	NA	1.42	
201 Meat Products	52	58.5	0.89	1, 2, 3
203 Canned Foods			4.20	4
208 Beverages	NA	NA	0.20	5, 6, 7, 8, 9, 10
2261 Finishing Cotton	720	160	4.50	11, 12, 13
2262 Finishing Synthetics	299	180	1.66	14, 13
2231 Finishing Wool	1872	950	1.97	11, 13
261, 265 263 266 Pulp, Paper and Paperboard Mills	975	50	1.95	15
28 Chemical Industry	(see Table VI-2)			16
2812 Alkalis and Chlorine	800	70	11.40	17
282 Plastic Materials and Synthetics	143	31	0.22	18, 19
2821 Plastic Materials and Resins	30	102	0.30	18, 19
2822 Synthetic Rubber	31	93	0.33	18, 19
2823 Cellulosic Manmade Fibers	36	373	0.10	18, 19
2824 Organic Fibers, Noncellulosic	35	260	0.14	18, 19
2871 Fertilizers	950	20.5	46.20	20
29 Petroleum and Coal Products	3.7	3.95	0.96	21, 22, 23
2911 Petroleum Refining	3.7	3.95	0.96	21, 22, 23
3111 Leather Tanning and Finishing	650	278	2.34	24, 25
3292 Asbestos Products	187000	8	Neg.	26
331 Primary Metal Industries	72.5	40.3	1.80	27, 28
3312 Blast Furnaces and Steel Mills	72.5	40.3	1.80	27, 28
333 Primary Nonferrous Metals	1250	112.5	11.10	29
3331 Primary Copper	3000	91.3	33.00	29
3332 Primary Lead	159	49.7	3.2	29
3333 Primary Zinc	177.5	55.5	3.2	29
3334 Primary Aluminum	910	128.5	7.1	29, 30

(1) NA—Not applicable. The waste factors shown in Column (5) were not computed, but obtained directly from the literature.

(2) Neg.—Negligible. The value added factor is so low that the computation of a waste factor on that basis would be misleading.

the MCA, waterborne inorganic and organic effluents were reduced by 27 percent and 57 percent respectively through treatment, and the airborne wastes were reduced by 65 percent.

Table III-3 shows the total annual waste per employee, the total number of employees, and value added by the chemical industry in each state. Waste factors were developed by multiplying the waste per employee factors by total number of employees, then dividing by the total value added. The range of waste factors shown in the table vary from 0.65 for Indiana to 63.9 for Arkansas. The waste factors for the states of Arkansas and Florida are high because they include large amounts of fertilizer, mining and processing wastes. The average waste factor applicable over the whole United States was computed without using the factors for these two states.

(3) Computation of Waste Quantities

Quantities of wastes were computed by multiplying the value added by the waste factors. Tables III-4 and III-5 show the computed quantities of waste produced by each of the significant industries in the 50 states and the 50 largest SMSAs, respectively.

(4) Sources of Data

The two types of data used in quantification of wastes are industry production data and waste production data.

1. Industry Data

Value added figures used in the computations were taken from the 1967 Census of Manufactures. Dun and Bradstreet data files were also considered as an alternative source, but were not used due to the relative difficulty of their direct application compared with that of the Bureau of Census data.

2. Waste Production Data

An intensive literature search and interviews with people in industry uncovered few data sources which identified and quantified the waste from different industries.

Table III-3

Chemical Industry Waste Factors

State	Annual Total Waste Per Employee $\frac{\text{ton/employee}}{\text{year}}$ x 10^3	All Employees (1000)	Value Added (million $)	Waste (million tons)	Waste Factor #/$ Value Added
Alabama	0.052	11.7	418.2	0.608	2.91
Arizona (also includes Utah Nevada, New Mexico, Oklahoma)	0.074	3.9	77.4	0.289	7.46
Arkansas	0.756	4.1	96.9	3.099	63.95
California	0.178	42.0	116.7	7.476	13.39
Colorado	0.013	1.9	61.1	0.025	0.81
Connecticut	0.023	11.5	378.8	0.265	1.40
Delaware	0.070	9.4	263.1	0.658	5.00
Florida	0.69	20.7	466.1	14.283	61.29
Georgia	0.133	11.7	308.1	1.556	10.10
Idaho (also includes Minnesota, Montana)	0.250	13.1	435.1	3.275	15.05
Illinois	0.253	57.4	1565.8	14.522	18.55
Indiana	0.011	94.7	832.9	0.272	0.65
Iowa	0.111	5.3	243.6	0.588	4.83
Kansas	0.023	10.1	276.3	0.232	1.68
Kentucky	0.118	13.3	391.6	1.569	8.02
Louisiana	0.367	19.1	679.5	7.010	20.63
Maine (also includes New Hampshire, Rhode Island, Vermont)	0.011	4.9	74.3	0.054	1.45
Maryland	0.090	17.6	422.5	1.584	7.50
Massachusetts	0.017	17.0	367.1	2.89	1.57
Michigan	0.151	37.2	1039.6	5.617	0.81
Mississippi	0.029	5.2	157.5	0.151	1.91
Missouri	0.091	22.3	545.8	2.029	7.44
New Jersey	0.052	97.3	2822.1	5.060	3.59
New York	0.091	63.4	1639.7	5.769	7.04
North Carolina	0.159	17.7	370.6	2.814	15.19
Ohio	0.141	47.7	1358.6	6.726	9.90
Oregon	0.051	2.0	50.8	0.102	4.02
Pennsylvania	0.023	49.5	1361.1	1.139	1.67
South Carolina	0.009	19.9	474.6	0.179	0.76
Tennessee	0.116	52.1	1155.5	6.044	10.46
Texas	0.105	47.9	2076.7	5.030	4.84
Virginia	0.138	40.9	762.0	5.644	14.81
Washington	0.023	6.4	166.0	0.147	1.77
West Virginia	0.082	22.5	836.3	1.85	4.41
Wisconsin	0.010	0.5	257.4	0.095	0.74
				108.65	

Table III-4
Waste Quantities Produced by Industry by Geographic Location - 50 States
(In Million Pounds Per Year)

Geographic Areas / Industries	20 Food	201 Meat Products	203 Canning	208 Beverages	2261 Finishing Cotton	2262 Finishing Synthetics	2231 Finishing Wool	261, 63, 65, 66 Pulp Paper and Paper Board Mills	28 Chemical Industry	2812 Alkalies and Chlorine	282 Plastics and Synthetics	2871 Fertilizers	29 Petroleum Products	2911 Petroleum Refining	3111 Leather Tanning	331 Primary Metals	3312 Blast Furnaces and Steel Mills	333 Primary Nonferrous Metals
Waste Factors (Pounds/$ Value Added)	1.42	0.89	4.2	0.20	4.5	1.66	1.97	1.95	.	11.4	0.22	46.2	0.96	0.96	2.34	1.80	1.80	11.1
United States Total Value Added (Million Dollars)	26.621	3.551	3.588	4.790	314	271	429	4,199	23,555	419	3,799	434	5,426	4,745	319	10,170	8,910	1,382
Waste Quantity	37.900	3.200	15.100	1.000	1,400	500	800	8,200	217,000	4,800	800	20,100	5,200	4,600	800	18,300	16,000	15,300
STATES																		
ALABAMA	370	55	50	10	70	.	20	390	1.220	190	15	1.685	40	35	.	670	635	500
ALASKA	75		190	.	.	.	.	65	.	.	.	.	.	.	.	.	.	.
ARIZONA	120	10	15	5	.	.	.	15	120	.	.	.	.	.	.	.	.	505
ARKANSAS	375	55	205	10	5	.	.	.	680	.	.	.	40	30	.	.	.	500
CALIFORNIA	4.255	230	3.310	95	20	5	5	.	14.955	185	20	1.180	530	480	20	680	670	110
COLORADO	440	60	45	20	.	.	.	.	45	.	.	.	50	50	.	90	90	.
CONNECTICUT	280	10	40	10	5	5	20	.	530	.	10	.	.	10	.	180	180	.
DELAWARE	225	15	115	.	30	.	.	10	1.315	30	15	45	30	30	45	55	55	.
FLORIDA	895	45	810	20	.	.	.	341	3.260	.	15	772	10	.	.	30	20	.
GEORGIA	795	90	20	20	80	5	55	572	2.110	30	5	625	15	.	5	35	30	.
HAWAII	265	5	290	.	.	.	.	.	.	.	.	.	15	10	.	5	5	.
IDAHO	205	15	295	.	.	.	.	15	1.665	.	.	310	.	.	.	.	.	335
ILLINOIS	3.580	185	825	80	10	5	5	120	29.045	.	15	2,500	370	285	55	1.495	1.345	125
INDIANA	1.080	85	255	40	.	.	.	55	540	.	5	250	210	190	5	3.270	2.020	500
IOWA	1.165	305	70	5	.	.	.	15	1.180	.	10	450	.	.	.	22	.	.
KANSAS	395	80	40	5	.	.	.	10	465	190	5	.	175	170	.	.	.	.
KENTUCKY	730	35	45	70	.	.	.	.	3.140	.	30	.	30	30	10	280	270	.
LOUISIANA	650	30	155	15	.	.	.	380	14.020	190	20	1,600	330	315	10	.	.	500
MAINE	230	10	215	.	.	.	65	.	15	.	.	.	.	.	50	.	.	.
MARYLAND	750	60	245	35	15	5	15	95	3.170	.	15	345	75	5	5	100	100	500
MASSACHUSETTS	805	50	250	15	90	70	105	290	575	.	25	.	75	.	145	115	75	.
MICHIGAN	1.320	75	555	30	.	5	.	300	840	15	30	215	105	90	35	1.005	850	110
MINNESOTA	1.075	200	35	25	.	.	5	[illegible]	3.395	.	.	120	45	40	10	60	50	.
MISSISSIPPI	225	40	20	5	.	.	.	70	300	.	.	200	30	30	.	10	5	.
MISSOURI	1.140	115	185	50	.	.	.	.	4.060	.	.	360	55	50	10	175	170	110

Table III-4 (Continued)

Geographic Areas \ Industries	20 Food	201 Meat Products	203 Canning	208 Beverages	2261 Finishing Cotton	2262 Finishing Synthetic	2231 Finishing Wool	261, 63, 65, 66 Pulp Paper and Paper Board Mills	28 Chemical Industry	2812 Alkalies and Chlorine	282 Plastics and Synthetics	2871 Fertilizers	29 Petroleum Products	2911 Petroleum Refining	3111 Leather Tanning	331 Primary Metals	3312 Blast Furnaces and Steel Mills	333 Primary Nonferrous Metals
MONTANA	80	10	-	-	-	-	-	5	125	-	-	-	40	30	-	-	-	700
NEBRASKA	610	165	70	5	-	-	-	-	1.380	-	-	-	5	-	-	-	-	100
NEVADA	20	-	-	10	-	-	-	-	180	90	-	-	-	-	-	-	-	110
NEW HAMPSHIRE	55	10	-	15	10	5	55	100	10	-	-	-	-	-	20	10	-	-
NEW JERSEY	1.790	65	670	60	70	130	10	230	10.130	35	-	360	190	18	65	150	70	410
NEW MEXICO	60	10	-	-	-	-	-	-	35	-	-	-	15	10	-	-	-	35
NEW YORK	2.790	140	240	80	85	45	70	395	11.520	50	15	-	75	70	60	840	830	705
NORTH CAROLINA	575	65	120	10	285	100	65	325	5.630	-	45	430	5	5	5	10	5	215
NORTH DAKOTA	60	5	10	-	-	-	-	-	-	-	-	-	15	-	-	-	-	-
OHIO	1.860	140	760	40	10	5	10	460	13.450	700	30	700	215	155	18	3.045	2.375	585
OKLAHOMA	250	35	30	5	5	-	-	20	145	-	-	-	140	140	-	10	10	500
OREGON	425	20	460	5	-	-	10	240	830	45	-	-	10	-	-	22	22	50
PENNSYLVANIA	2.335	155	1.010	45	50	20	40	380	2.275	-	50	360	300	245	45	5.065	4.790	705
RHODE ISLAND	100	-	5	5	50	35	35	-	70	-	10	-	-	-	-	50	20	-
SOUTH CAROLINA	170	35	45	5	595	65	85	265	360	-	50	385	-	-	-	10	5	-
SOUTH DAKOTA	135	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TENNESSEE	650	65	100	15	70	20	15	210	12.090	100	85	320	10	10	20	55	30	655
TEXAS	745	155	425	45	-	-	5	200	10.050	500	65	1.940	1.730	1.695	5	345	340	2.520
UTAH	145	20	35	5	-	-	-	-	100	-	-	-	50	50	-	80	80	50
VERMONT	55	-	-	-	-	-	-	30	10	-	-	-	-	-	5	-	-	-
VIRGINIA	560	65	230	10	35	30	50	330	11.285	500	105	535	16	16	20	20	20	-
WASHINGTON	735	45	595	15	-	-	10	600	295	220	-	-	60	60	-	65	60	2.070
WEST VIRGINIA	125	10	40	5	-	-	-	5	3.690	670	45	-	10	10	20	545	530	500
WISCONSIN	1.295	100	475	55	15	10	5	710	190	-	5	-	10	5	120	85	80	-
WYOMING	20	-	-	-	-	-	-	-	-	-	-	-	35	35	-	-	-	-

Table III-5
Waste Quantities Produced by Industry by Geographic Location 50 Largest Standard Metropolitan Statistical Areas (In Million Pounds Per Year)

Geographic Areas / Industries	20 Food	201 Meat Products	203 Canning	208 Beverages	2261 Finishing Cotton	2262 Finishing Synthetic	2231 Finishing Wool	261, 63, 65, 66 Pulp Paper and Paper Board Mills	28 Chemical Industry	2812 Alkalies and Chlorine	282 Plastics and Synthetics	2871 Fertilizers	29 Petroleum Products	2911 Petroleum Refining	3111 Leather Tanning	331 Primary Metals	3312 Blast Furnaces and Steel Mills	333 Primary Nonferrous Metals
Waste Factors (Pounds/$ Value Added)	1.42	0.89	4.2	0.20	4.5	1.66	1.97	1.95		11.4	0.22	46.2	0.96	0.96	2.34	1.80	1.80	11.1
St::dard Metropolitan Statistical Areas																		
New York, N.Y.	1,400	71	235	55	75	30	20	15	6,265		5		25					
Chicago, Ill.	2,305	115	310	50				15	21,620				145			1,030	905	
Los Angeles - Long Beach, Calif.	1.345	120	480	35					8,330		20		200	250		200		
Detroit, Mich.	465	50	40	20					260				65			960		
Philadelphia, Pa. - N.J.	1.075	85	535	20	35	15	25	175	1.700		35		280	245	10	735	625	140
Cleveland, Ohio	260	10	130	10					2.975		10		25			590	560	
St. Louis, Mo.-Ill.	695	65		50					9,050			15	185	170	10			100
Boston, Mass.	535	45	135	10					240				10		110	15		
Newark, N.J.	505	25	45	35				60	4,015		16				50	30		
Pittsburgh, Pa.	345	20		5					215									
San Francisco - Oakland, Calif.	975	40	540	25					3.855			220	205					
Milwaukee, Wis.	545	30	35	45					50						85	60		
Rochester, N.Y	750	15	602	10					360									
Houston, Tex.	380	15	20	5					4,050		30	1.325	530	525				
Baltimore, Md.	520	35	35	30					2.410			345	10					
Minneapolis - St. Paul, Minn.	455	60		20					2.910									
Cincinnati, Ohio-Ky.-Ind.	590	25	70	35				55	5.290									
Buffalo, N.Y.	325	20	115	5					1.600		10		35			640	590	
Paterson - Clifton - Passaic, N.J.	295		70	5	30	95		40	1.370				10			20		
Louisville, Ky - Ind.	405	20	30	35					205		30							
Kansas City, Mo -Kans.	320	30		5					1.250									
Seattle - Everett, Wash.	215	20	85	5					40				5					
Anaheim - Santa Ana - Garden Grove, Calif.	200	4	140	5					590									
Dayton, Ohio	115	20		5				55	310									
San Jose, Calif.	550	10	515	5														
Indianapolis, Ind.	210		60	5					185									
Dallas, Tex.	335	40	25	10					600				10					
Gary-Hammond - East Chicago, Ind.	90	5							95				190	180		1.875	1,815	
Atlanta, Ga.	270	10	40	10					995									
Jersey City, N.J.	440	20		10	15	20			920									
Greensboro - Winston-Salem - High Point, N.C.	85	10			70	15			985									
Providence - Pawtucket - Warwick, R.I.	100			5	50	20	20		70		5				50			
Hartford, Conn.	100			5					25									
Akron, Ohio	100								855									
Youngstown - Warren, Ohio	35								100							810		
Toledo, Ohio - Mich.	150	5	100										105	100		40		
Fort Worth, Tex.	125	20		5					125				10					
Beaumont - Port Arthur - Orange, Tex.	20								1.300				740					
Columbus, Ohio	175	15	25						455			160						
Bridgeport, Conn.	30								30									
Denver, Colo.	300	30	30						40									
Portland, Oreg. - Wash.	240	10	95	10				190	135				10					
Allentown - Bethlehem - Easton, Pa. - N.J.	135	5			15	10			100									
Grand Rapids, Mich.	95	5	60						70									
Springfield - Chicopee - Holyoke, Mass. - Conn.	60							55	170							30		
Syracuse, N.Y.	150		25					20	1.000									
Birmingham, Ala.	120	10							85				5			490		
Canton, Ohio	85	25							220							450		
Alabany - Schenectady - Troy, N. Y.	115	20		5				90	690									
New Orleans, La.	295	5	65	5					1,000				30					

Most of the data available were in terms of quantity of waste discharged to aquatic environment. The industrial waste studies sponsored by EPA were heavily used, along with information provided by the trade associations. The references used are listed at the end of this chapter.

(5) Assumptions Used in Estimating Waste

Some assumptions made during the process of estimating waste quantities are applicable to all the industries, while others apply specifically to a single industry.

1. Overall General Assumptions

The two major assumptions generally applicable to all the industries are:

- Technology within an industry is homogeneous and does not change according to geographic location, therefore a single waste factor can be used to compute amount of waste across the country.
- Industry production data used are for the year 1967. Therefore, the waste quantities estimated are for that year, but these estimates can be used for the present level of industry, since the changes in production quantity and improvements in waste reduction technology are assumed to offset each other.

2. Specific Assumptions Applicable to Industries

Some of the assumptions used to compute waste quantities for specific industries are presented in this section.

- Food Industry—Canning waste does not include those wastes left in the field from harvesting, which are considered agricultural wastes. Meat processing waste does not include hair and blood which are routinely collected and sold as by-products. Also, wastes from stockyards and pens are not included in the wastes considered here.

- Textile Industry—The wastes included in this study are only those from wet finishing operations: the fiberous wastes from dry processing, knitting and weaving, etc., are not included.

- Pulp, Paper, and Paperboard Industry—The paper and wood chips waste from wood cutting and cleaning are not considered. The wastes from pulp, paper, and paperboard-making are the ones accounted for in this study. Further, the by-products made from the black liquor are not included.

- Fertilizers—Wastes produced in mining of phosphates are considered as mining waste and therefore do not add to fertilizer industry wastes.

- Petroleum Products Industry— Brines from the earth are pumped back to earth. Therefore, the brines do not contribute to the potentially hazardous wastes of this industry.

- Primary Nonferrous Metals—Mining operation wastes arenot considered to be waste from this industry, but from the mining industry.

(6) Reasons for Presenting Data by 50 States and 50 SMSAs

The quantities of waste produced by the industries have been computed for all the 50 states, and for the 50 largest SMSAs. Presenting waste data by the 50 states provides full coverage of the whole United States, while presenting the data by SMSA isolates the waste location to a small geographic area. The SMSA data is computed for only the 50 largest SMSAs for three reasons: first, all 231 SMSAs represent only about 75 percent of the total manufacturing industry; second, the detailed value added figures for the smaller SMSAs are not collected by the Bureau of Census; and third, some states with smaller SMSAs had as little as 15 percent of the value added industries within the SMSA.

(7) Other Quantitative Data

Other quantitative data helpful to an understanding of the problems associated with waste generation and disposal are interspersed throughout the report. Each of the industrial descriptions contained in Appendix A provides information as to:

- Relative size of the industrial sector
- Number of establishments and geographic distribution
- Economic data as to size of establishments and number of employees
- Growth patterns.

Many of the industrial sector descriptions contain additional data relating to the products made, processes used and wastes produced. Special studies which contain detailed data of significant value are also referenced in these descriptions.

4. ESTIMATES OF COMMONLY KNOWN MIXED WASTE STREAMS, WITH BREAKDOWNS OF SPECIFIC HAZARDOUS MATERIALS

Among the various industries, certain production processes are in use which produce mixed wastes that are also similar throughout these industries. Over the years, many of these mixed waste streams have come to be known by common or "trade" names, which generally refer to their color, appearance, odor, etc. While such waste streams have seldom been analyzed in detail or subjected to continuous analysis, at least parts of their make-up have been identified and reported in the literature. During the course of this study, it was found that some of these commonly-known waste streams do have as inputs, at least some of the materials that have been designated as hazardous. In a few instances, data were obtained which not only gave waste stream quantity generation as a function of production, but also provided some measure of specific materials that might typically be contained.

Where such data were available, they have been extracted and tabulated. The waste stream quantities and the specific hazardous materials contained have been extrapolated to produce estimates, on a regional geographic basis, for certain industries.

(1) Methodology for Estimating Waste Streams and Specific Hazardous Material Quantities

The literature referencing the industrial sectors within the scope of the study was surveyed to obtain available information for quantitatively correlating the list of hazardous substances with industrial wastes. These wastes are generally not homogeneous. Rather, in each waste a complex mix of specific components are found. A given chemical, identified as hazardous, is most often to be found in such a situation.

The procedure used in accomplishing this task was, in sequence:

- Identify the waste source by industrial sector
- Identify the waste stream and the component(s) in the stream that are correlatable to the list of hazardous substances
- Develop quantity estimates of the production, in industrial waste, of each identifiable hazardous substance, using whatever quantification factors are available in the literature, i.e., percentages or ratios of each substance in the waste stream were used directly from the literature.

A set of tables across the various industrial sectors were developed using these procedures (Table III-6). A general comment is that the hazardous waste quantities indicated present boundary, or "ballpark," figures of production rates of these unwanted substances. A further note of explanation is that often the literature reports a component in simple terms, such as "chromium," even though the more accurate expression might be "dichromate". In assigning identification numbers from the list of hazardous substances to specific waste components, the following ground rules were used:

Table III-6
Hazardous Materials Expected in Waste Streams of Producers and Users

WASTE SOURCE		WASTE TYPE			ANNUAL PRODUCTION OF HAZARDOUS WASTE QUANTITIES														
							NORTHEAST REGION			NORTH CENTRAL REGION			SOUTHERN REGION				WESTERN REGION		
SIC	DESCRIPTION	I.D. #	DESCRIPTION OF HAZARDOUS COMPOUNDS	GENERAL QUANTIFICATION FACTORS	UNITS	TOTAL U.S.	New England Division	Middle Atlantic Division	Total	E. North Central Division	W. North Central Division	Total	South Atlantic Division	E. South Central Division	W. South Central Division	Total	Mountain Division	Pacific Division	Total
22	Textile Mill Products																		
223	. Wool		Raw Waste	Up to 70,000 gal./1,000 lb. product	Million gal.														
		2	. Acetic Acid	20 ppm, 12 lb./1,000 lbs.	1,000 lbs.	5,000	850	350	1,200	75	25	100	3,000	400	60	3,460			100
		382	. Sulfuric Acid	4 ppm, 2 lb/1,000 lbs.	1,000 lbs.	820	50	160	210	28	3	30	400	80	10	485			2
		350	. Chrome Mordant $(Na_2Cr_2O_7 + (NH_4)_2S)_4$	8 ppm, 4 lb./1,000 lbs.	1,000 lbs.	1,440	100	320	420	35	6	41	800	110	20	1,170			4
		350	. Chrome $(Na_2Cr_2O_7)$	12 ppm, 4 lb/1,000 lbs.	1,000 lbs.	2,470	110	500	610	66	10	85	1,470	240	30	1,760			6
221 225 226 228	. Cotton		Raw Waste	55,000 gal./1,000 lbs. product															
		363	. Caustic Soda	722 ppm	1,000 gal.	60,000	4,140	11,400	15,500	1,000	150	1,200	30,000	3,600	400	42,000			60
		367	. Phosphoric Acid	12 ppm	1,000 gal.	1,360	110	280	390	25	5	30	890	160	15	1,070			.5
		357	. Chromium	2 ppm	1,000 gal.	230	16	44	60	3	1	4	145	23	2	170			2
		410	. Zinc	0.7 lb./1,000 lbs. goods--cotton or 50/50 cotton/polyester	1,000 lbs.	1,300	110	280	390	25	5	30	890	160	12	1,070			.5
		126	. Copper	3 lb./1,000 lbs. from sulfur dying of cotton yarn	1,000 lbs.	6,000	415	1,160	1,575	100	15	120	3,900	340	60	4,300			4
229	. Polyester	399	. Trichlorobenzene	--															
229	. Other		Raw Waste	9,000 gal./1,000 lbs. product															
		126	. Copper	25 to 50 ppm	1,000 lbs.	2,000	140	370	520	30	8	40	1,200	180	25	1,410			2
		365	. Phenols	100 to 150 ppm	1,000 lbs.	16,000	1,120	3,040	4,160	240	75	320	9,600	1,500	160	11,440			15
261 262 263 266	Pulp, Paper, and Board Mill		. Black Liquor	400 gals./ton	Million gal.	40,000	4,600	4,700	9,300	7,200	1,600	8,800	9,500	3,000	3,600	16,100	900	4,700	5,600
			. Black Liquor Solids	600 lbs./ton	Million gal.	50,000	3,700	7,700	11,400	8,100	2,900	11,000	11,300	4,300	4,800	20,400	1,100	5,900	7,000
			. Resin Acids																
		265	. Methyl Mercaptan	5.3 lbs./ton	Million lbs.	400	44	47	91	72	16	88	80	34	48	162	9	47	56
		406	. Zinc Hydrosulfide																
		255	. Methanol																
		210	. Hydrogen Sulfide	0.04 lbs./ton	1,000 lbs.	55,000	6,300	6,300	12,600	10,000	2,200	12,200	12,400	6,700	3,300	22,400	1,200	6,500	7,700
		390	. Sulfur Dioxide																
		266	. Methyl Isobutyl Ketone																
28	Chemicals and Allied Products																		
2812	Alkalies and Chlorine Industry		Cell Process Waste																
		382	. Sulfuric Acid	17 lbs./ton	1,000 lbs.	170,000	200	12,200	12,400	14,300	1,900	16,200	21,000	15,000	90,000	128,400	3,700	7,500	11,200
		103	. Calcium Oxide	8 lbs./ton of down cell Cl_2		NA													
		384	. Sodium Carbonate	2 lbs./ton of down cell Cl_2		NA													
		232	. Mercury	.19 lbs./ton	1,000 lbs.	1,800	--	130	130	170	25	195	230	170	960	1,360	40	80	120
		53	. Asbestos	.8 lbs./ton	1,000 lbs.	900	--	65	65	85	10	95	115	85	480	680	20	40	60
		228	. Lead	0.36 lbs./ton	1,000 lbs.	3,500	5	255	260	360	10	370	450	330	1,870	2,650	80	160	240
			. Chlorinated Hydrocarbons	1 lb./ton	1,000 lbs.	10,000	15	720	735	960	110	1,070	1,280	830	5,360	7,500	220	440	660

Table III-6
(Continued)

WASTE SOURCE		WASTE TYPE					ANNUAL PRODUCTION OF HAZARDOUS WASTE QUANTITIES												
							NORTHEAST REGION			NORTH CENTRAL REGION			SOUTHERN REGION				WESTERN REGION		
SIC	DESCRIPTION	I.D. #	DESCRIPTION OF HAZARDOUS COMPOUNDS	GENERAL QUANTIFICATION FACTORS	UNITS	TOTAL U.S.	New England Division	Middle Atlantic Division	Total	E. North Central Division	W. North Central Division	Total	South Atlantic Division	E. South Central Division	W. South Central Division	Total	Mountain Division	Pacific Division	Total
			Purification sludge	34 lbs./ton	Million lbs.	500		60	60	50	5	56	60	65	170	300	10	20	30
2815 2818	Cyclic Intermediates Industrial Organic Chemicals																		
	. Phenol Production		Benzene Sulfonate Process Waste	5,900 lbs./ton Prod.	Million lbs.	170				90		90		80		80			
		60	. Benzene	--															
		302	. Sulfuric Acid	--															
		363	. Caustics	--															
			Cumene Oxidation Process Waste	200 lbs./ton Prod.	1,000 lbs.	37,000		20,000	20,000	5,000	5,000	10,000			6,000	6,000		1,000	1,000
		316	. Polychlorinated Benzenes	--															
		305	. Tar	--															
			Chlorination of Benzene Process	670 gals./1,000 lbs. Prod.	1,000 gals.	80,000		2,700	2,700	63,000		63,000		16,000		16,000			
		112	. Organic Chloride	50 lbs./1,000 lbs. Prod.	1,000 lbs.	7,000		3,100	3,100	40,000		40,000		12,000		12,000			
		305	. Phenol	5 lbs./1,000 lbs. Prod.		700		210	210	4,000		4,000		1,200		1,200			
	. Ethylene via Thermal Pyrolysis		Raw Waste	--															
		305	. Phenols	0.1 lbs./1,000 lbs. Prod.	1,000 lbs.	1,600							NA						
		105	. Organic Chlorides	0.03 lbs./1,000 lbs. Prod.	1,000 lbs.	300							NA						
	. Acetaldehyde via Ethylene Oxidation		Acetaldehyde Still Bottoms	--															
		600	. Organic Chlorides	65 lbs./1,000 lbs. Prod.	1,000 lbs.	75,000							10,000		65,000	75,000			
	. Acetone		Cumene Process Waste	500 gals./1,000 lbs. Prod.	Million gals.	600		100	100	100		200		60	250	310		15	15
		305	. Phenol	24 lbs./1,000 lbs. Prod.	1,000 lbs.	25,000		8,000	8,000	4,000		4,000		2,500	10,000	12,500		600	600
	. Adipic Acid via Cyclohexane Oxidation		Raw Waste	1,700 gals./1,000 lbs. Prod.	Million gals.	1,870							1,100	70	700	1,870			
		126	. Copper	0.3 lbs./1,000 lbs. Prod.	1,000 lbs.	330							200	5	25	330			
		---	. Vanadium	0.06 lbs./1,000 lbs. Prod.	1,000 lbs.	66							40	1	25	66			
		151	. Cobalt	0.001 lbs./1,000 lbs. Prod.		Neg.							Neg.	Neg.	Neg.	Neg.			
	. Butadiene via N-Butane Dehydrogenation		Raw Waste	2,400 gals./1,000 lbs. Prod.	Million gals.	9,000				300		300			8,300	8,300		400	400
		110	. Chromium	0.07 lbs./1,000 lbs. Prod.	1,000 lbs.	265				10		10			245	245		15	15
		---	. Organic Chloride	6.3 lbs./1,000 lbs. Prod.	1,000 lbs.	23,000				800		800			22,000	22,000		1,200	1,200
		373	. Sulfides	0.3 lbs./1,000 lbs. Prod.	1,000 lbs.	1,140				40		40			1,000	1,000		100	100
	. Formaldehyde via Methanol Oxidation		Raw Waste	480 gals./1,000 lbs. Prod.	Million gals.	2,400				50		50	100		2,200	2,300			
		110	. Chromium	0.0037 lbs./1,000 lbs. Prod.	1,000 lbs.	20				1		1	2		10	10			
		106	. Organic Chloride	0.16 lbs/1,000 lbs. Prod.	1,000 lbs.	800				20		20	40		730	770			
		114																	
		147																	
	. Methanol via Carbon Monoxide Synthesis		Raw Waste	1,612 lbs./1,000 lbs. Prod.	Million lbs.	11,000				250		250	500		10,000				
		---	. Organic Chlorides	0.10 lbs./1,000 lbs. Prod.	1,000 lbs.	1,200				21		20	55		1,100				
		118	. Chromium	0.01 lbs./1,000 lbs. Prod.	1,000 lbs.	70				2		2	3		65				
		418	. Zinc	0.011 lbs./1,000 lbs. Prod.	1,000 lbs.	80				2		2	4		73				
	. Ethylene Dichloride via Oxy-Chlorination of Ethylene		Raw Waste	350 gals./1,000 lbs. Prod.	Million gals.	2,400								200	2,100	2,300		100	100
		115	. Organic Chlorides	32 lbs./1,000 lbs. Prod.	1,000 lbs.	24,400								2,400	21,000	23,400		1,000	1,000

Table III-6
(Continued)

WASTE SOURCE		WASTE TYPE					ANNUAL PRODUCTION OF HAZARDOUS WASTE QUANTITIES												
							NORTHEAST REGION			NORTH CENTRAL REGION			SOUTHERN REGION				WESTERN REGION		
SIC	DESCRIPTION	I.D. #	DESCRIPTION OF HAZARDOUS COMPOUNDS	GENERAL QUANTIFICATION FACTORS	UNITS	TOTAL U.S.	New England Division	Middle Atlantic Division	Total	E. North Central Division	W. North Central Division	Total	South Atlantic Division	E. South Central Division	W. South Central Division	Total	Mountain Division	Pacific Division	Total
2819	**Industrial Inorganic Chemicals**																		
	. Phosphorus	309	. Phosphorus	12 lb/ton	1,000 lbs.	8,400							700	4,100		4,800	3,600		3,600
		371	. Phosphate (soluble)	10.5 lbs./ton	1,000 lbs.	7,400							600	3,600		4,200	3,200		3,200
		359	. Fluoride	8 lbs/ton	1,000 lbs.	5,600							450	2,700		3,200	2,400		2,400
	. Phosphoric Acid (Wet Process)		. Pond Settling	1644 lbs./ton product	Million lbs.	6,200													
		100	- Calcium Fluoride	68 lbs./ton product	1,000 lbs.	340,000													
		307	- Phosphoric Acid	1 lb./ton product	1,000 lbs.	5,000													
		371	- Phosphate	45 lbs./ton product	1,000 lbs.	225,000													
	. Hydrogen Peroxide	216	. Hydrogen Peroxide	40 lbs./ton product	1,000 lbs.	2,800													
	. Aluminum Chloride	109	. Chlorine	8 lbs./ton product	1,000 lbs.	200		100	100	100		100							
		212	. Hydrochloric Acid	8 lbs./ton product	1,000 lbs.	200		100	100	100		100							
	. Aluminum Sulfate		. Settling Pond Mund	350 lbs./ton	Million lbs.	350	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
		382	- Sulfuric Acid	10 lbs./ton product	1,000 lbs.	10,000	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	. Hydrochloric Acid	212	. Hydrochloric Acid	41 lbs./ton product	1,000 lbs.	74,000	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	. Nitric Acid		. Filter Aids																
		283	- Nitric Acid	6 lbs/ton product	1,000 lbs.	38,000	1,000	2,000	3,000	7,000	5,000	12,000	5,000	5,000	10,000	19,000	3,600	400	4,000
	. Sulfuric Acid		. Neutralization Pond Settling	30 lbs/ton product	Million lbs.	840	10	125	135	20	160	180	160	100	160	420	20	60	80
			. Filter Aids																
		382	- Sulfuric Acid	1 lb./ton product	1,000 lbs.	28,000	300	4,200	4,500	900	5,100	6,000	5,600	3,000	5,600	14,000	400	1,100	1,500
	. Hydrofluoric Acid	100	. Calcium Fluoride	--															
		307	. Phosphoric Acid	--															
	. Sodium Dichromate	350	. Chromium Salts	1 lb./ton product	Million lbs.	300	35	65	100	5	63	70	50	30	35	115		10	10
282	**Plastics and Resins**																		
2821	Acrylics		Raw Waste	0.13 gals./lb. product	1,000 gals.	25,700	3,000	6,000	9,000	640	5,600	6,000	4,300	2,500	3,200	10,000		700	700
		12	. Acrylonitrile	--															
		200	. Formic Acid	--															
		412	. Vinyl Acetate	--															
		413	. Vinyl Chloride	--															
		379	. Styrene	--															

Table III-6
(Continued)

WASTE SOURCE		WASTE TYPE		GENERAL QUANTIFICATION FACTORS	ANNUAL PRODUCTION OF HAZARDOUS WASTE QUANTITIES													
SIC	DESCRIPTION	I.D.#	DESCRIPTION OF HAZARDOUS COMPOUNDS		UNITS	TOTAL U.S.	NORTHEAST REGION			NORTH CENTRAL REGION			SOUTHERN REGION				WESTERN REGION		
							New England Division	Middle Atlantic Division	Total	E. North Central Division	W. North Central Division	Total	South Atlantic Division	E. South Central Division	W. South Central Division	Total	Mountain Division	Pacific Division	Total
2821	. Alkyd and Polyester Resins		Raw Waste	2 gals./lb. product	Million gals.	2,400	260	540	800	50	450	500	400	200	300	900		70	70
		242	. Maleic Anhydride	--															
		379	. Styrene	--															
		336	. Propylene Glycol	--															
		314	. Phthalic Acid	--															
2821	. Urea and Melamine Resins		Raw Waste	0.1 gals./lb. product	Million gals.	60	6	14	20	1	9	10	10	5	5	20		--	--
		93	. Caustic	--															
2821	. Phenolic Resins		Raw Waste	0.1 gals./lb. product	Million gals.	100	10	25	35	2	18	20	20	10	10	40		3	3
		305	. Phenols	--															
		199	. Formaldehyde	--															
2821	. Cellulose Esters		Raw Waste	30 gals./lb product	Million gals.	14 400	1,600	3,300	4,900	330	2,700	3,000	2,400	1,000	1,600	5,000		400	400
		2	. Acetic Acid	--															
		382	. Sulfuric Acid	--															
		247	. Mercury Chlorides	--															
2821	. Vinyl Resins		Raw Waste	1.5 gals./lb. product	Million gals.	4,500	500	1,000	1,500	110	900	1,000	800	400	500	1,700		130	130
		305	Phenols	--															
		106	. Carbon Tetrachloride	--															
		114	. Chloroform	--															
2821	. Polystyrene Resins and Copolymers		Raw Waste	1.5 gals./lb. product	Million gals.	4,400	500	1,000	1,500	100	800	900	700	400	500	1,600		120	120
		259	. Methylal	--															
2823	. Rayon Fibers	418	Zinc Salts	12-50 lbs. Zn/1,000 lb. product	Million lbs.	12-50													
287	Agricultural Chemicals																		
	. Ammonium Nitrate		Raw Waste	--															
		24	. Ammonium Nitrate	14 lbs./ton	1,000 lbs.	121,000	2,000	5,000	7,000	35,000	15,000	50,000	15,000	15,000	18,000	48,000		15,000	15,000
		19	. Ammonia	lbs./ton	1,000 lbs.	43,000	1,000	2,000	3,000	12,000	7,000	19,000	5,000	5,000	7,000	17,000		5,000	5,000
	. Ammonium Sulfate		Raw Waste	--															
		357	. Chromate	35 lbs./1,000 tons product	1,000 lbs.	40	Negligible			Negligible			Negligible				Negligible		
	. Urea		Raw Waste	--															
		--	. Urea	67 lbs./ton	Million lbs.	360		15	15	35	65	100	35	50	100	190		80	80
		19	. Ammonia	14 lbs./ton	Million lbs.	10		5	5	10	20	30	10	20	30	50		15	15
		357	. Chromate	41 lbs./1,000 tons product	1,000 lbs.	221	Negligible			Negligible			Negligible				Negligible		

Table III-6
(Continued)

WASTE SOURCE		WASTE TYPE		GENERAL QUANTIFICATION FACTORS	ANNUAL PRODUCTION OF HAZARDOUS WASTE QUANTITIES														
							NORTHEAST REGION			NORTH CENTRAL REGION			SOUTHERN REGION				WESTERN REGION		
SIC	DESCRIPTION	I.D. #	DESCRIPTION HAZARDOUS COMPOUNDS	–	UNITS	TOTAL U.S.	New England Division	Middle Atlantic Division	Total	E. North Central Division	W. North Central Division	Total	South Atlantic Division	E. South Central Division	W. South Central Division	Total	Mountain Division	Pacific Division	Total
	. Nitric Acid (as intermediate)		Raw Waste	--															
		283	. Nitric Acid	1,000 lbs./1,000 tons product	Included in 2819														
		307	. Chromate	39 lbs./1,000 tons product	1,000 lbs.	120													
		418	. Zinc	10 lbs./1,000 tons product	1,000 lbs.	30													
2892	Explosives																		
	. Smokeless Powder		Raw Waste	--															
		382	. Sulfuric Acid	1 lb./1 lb. product	Production Data Not Available.														
		283	. Nitric Acid	1 lb./1lb. product	See Table III-8 for Private Industry														
	. Nitroglycerin		Raw Waste	--															
		382	. Sulfuric Acid	5,100 lbs./100,000 lbs. pr product															
		283	. Nitric Acid	5,740 lbs./100,000 lbs. product															
	. TNT		Red Water	34 lbs./100 lbs. product															
		378	. Sodium Sulfite	2.3%															
		366	. Sodium Nitrite	3.5%															
		365	. Sodium Nitrate	1.7%															
		293	. Nitrotoluene	17.3%															
			. Primar Materials																
			- Lead Azide																
		230	- Lead Arsenate																
		231	- Lead Arsenite																
	. RDX		Raw Waste	--															
		2	. Acetic Acid	160 lbs./100 tons product															
		--	. RDX	1 lb./100 tons product															
		--	. Methyl Nitrate	200 lbs./100 tons product															
	. HMX		Raw Waste	--															
		2	. Acetic Acid	160 lbs./100 tons product															
		--	. HMX	2 lbs/100 tons product															
29	Petroleum and Coal Products																		
291	Petroleum Refining	306	. Phenols	16.[illegible]2 lbs./1,000 barrels of feed	1,000 lbs.	50,000		4,600	4,600	8,000	3,000	11,000	13,000	1,300	24,000	26,000	1,700	6,700	8,000
		173	. Sulfides	6.25 lbs./1,000 barrels of feed	1,000 lbs.	15,000		1,400	1,400	2,400	800	3,200	400	400	7,100	7,900	500	2,000	2,500
		19	. Ammonia	16.2 lbs./1,000 barrels of feed	1,000 lbs.	49,000		4,500	4,500	7,800	2,600	10,000	1,200	1,200	23,000	26,000	1,600	6,600	8,000
			. Sour Water	6-7 gals./gal. product	Million gals.	683,000		6,300	6,300	108,000	38,000	146,000	17,000	17,000	326,000	360,000	23,000	91,000	114,000
		373	- Sulfides	--															
		218	- Hydrogen Sulfide	--															
		29	- Ammonium Sulfide	--															
		306	- Phenol	--															
		253	- Mercaptans	--															

Table III-6
(Continued)

WASTE SOURCE		WASTE TYPE		GENERAL QUANTIFICATION FACTORS	UNITS	TOTAL U.S.	ANNUAL PRODUCTION OF HAZARDOUS WASTE QUANTITIES												
							NORTHEAST REGION			NORTH CENTRAL REGION			SOUTHERN REGION				WESTERN REGION		
SIC	DESCRIPTION	I.D. #	DESCRIPTION OF HAZARDOUS COMPOUNDS				New England Division	Middle Atlantic Division	Total	E. North Central Division	W. North Central Division	Total	South Atlantic Division	E. South Central Division	W. South Central Division	Total	Mountain Division	Pacific Division	Total
291	**Petroleum Refining** (Continued)																		
		182	- Ethyl Mercaptans	--															
		265	- Methyl Mercaptans	--															
		2	- Acetic Acid	--															
		131	- Cyanides	--															
			- Nitrogen Bases	--															
			. Spent Caustics	1-2 lbs./barrel of feed	Million lbs.	5,000		460	460	800	300	1,100	130	130	2,400	2,600	170	630	800
		4	- Methyl Sulfate	--															
		162	- Dinitro-o-cresols	--															
			. Spent Sulfuric Acid Sludge																
		[illegible]	- Sulfuric Acid																
			. Copper and Lead Bearing Waste																
		234	- Lead																
		235																	
		125	- Copper Nitrate																
		124	- Copper Cyanide																
			. Aldehydes	1.-19 lbs. 1,000 barrels of feed	1,000 lbs.	50,000		4,600	4,600	8,000	3,000	11,000	1,300	1,300	24,000	26,000	1,700	6,700	8,000
		1	- Acetaldehyde																
		[illegible]	- Butyl Aldehyde																
		199	- Formaldehyde																
		201	- Furfural																
			. Other Wastes																
		14	- Allyl Alcohol																
		31	- Amyl Alcohol																
		78	- Butanol																
		172	- Ethanol																
		221	- Isobutyl Alcohol																
		224	- Isopropyl Alcohol																
		255	- Methanol																
		60	- Benzene																
		76	- Butadiene																
		106	- Carbon Tetrachloride																
		178	- Ethyl Benzene																
		185	- Ethylene Dichloride																
		188	- Glycol																
		189	- Ethylene Oxide																
		206	- Formic Acid																
		386	- Tar																
		394	- Thallium																
		398	- Toluene																
		412	- Vinyl Acetate																
		116	. Chromic Acid																
		283	. Nitric Acid																
		307	. Phosphoric Acid																
		363	. Sodium Hydroxide																

Table III-6
(Continued)

WASTE SOURCE		WASTE TYPE		GENERAL QUANTIFICATION FACTORS	ANNUAL PRODUCTION OF HAZARDOUS WASTE QUANTITIES														
SIC	DESCRIPTION	I.D. #	DESCRIPTION OF HAZARDOUS COMPOUNDS		UNITS	TOTAL U.S.	NORTHEAST REGION			NORTH CENTRAL REGION			SOUTHERN REGION				WESTERN REGION		
							New England Division	Middle Atlantic Division	Total	E. North Central Division	W. North Central Division	Total	South Atlantic Division	E. South Central Division	W. South Central Division	Total	Mountain Division	Pacific Division	Total
291	**Petroleum Refining** (Continued)		. Heavy Metals (ion)	Industry Total Water Effluent (1.1×10^9 gal/day)															
		88	- Cadmium	0.03 ppm	1,000 lbs.	100		9	9	16	5	21	3	3	47	53	3	13	16
		118	- Chromium	0/14 ppm	1,000 lbs.	400		37	37	65	20	85	10	10	190	210	10	50	60
		126	- Copper	0.08 ppm	1,000 lbs.	200		18	18	30	10	40	5	5	95	105	50	25	30
		196	- Iron	0.43 ppm	1,000 lbs.	1,300		110	110	200	65	265	40	40	600	620	40	170	210
		--	- Lead	0.15 ppm	1,000 lbs.	300		30	30	50	15	65	10	10	150	160	10	40	50
		247	- Mercury	0.032 ppm	1,000 lbs.	100		9	9	16	5	21	3	3	47	53	3	13	16
		279	- Nickel	0.13 ppm	1,000 lbs.	400		37	37	65	20	85	10	10	190	210	10	50	60
		419	- Zinc	0.20 ppm	1,000 lbs.	600		66	60	100	30	130	20	20	300	320	20	80	100
31	**Leather and Leather Products**																		
311	**Leather Tanning and Finishing**		. Chrome Tan Liquor	--															
		357	- Chromium	9 lbs./1,000 lbs. hides	1,000 lbs.	18,000	4,100	5,300	9,400	5,300	500	5,800	1,400	800	100	2,300		500	500
		373	- Sulfides	3 lbs./1,000 lbs. hides	1,000 lbs.	6,000	1,400	1,700	3,100	1,700	200	1,900	400	200	30	800		200	200
32	**Stone, Clay, Glass and Concrete Products**																		
	. Mirror		Raw Waste	--															
		118	. Chromium	0.019 lbs/1,000 ft² product	1,000 lbs	2,000	100	500	600	500	--	500	500	200	50	950			
		196	. Iron	0.069 lbs./1,000 ft² product	1,000 lbs	7,000	700	1,800	2,500	1,600	100	1,700	2,000	700	300	3,000			
33	**Primary Metal Industries**																		
331	**Blast Furnaces, Steel Works, and Rolling and Finishing Mills**		Consolidated Plant Waste	1.37×10^6 gals/million dollar value added (M$VA)	10^9 gallons	1,500	30	500	530	630	20	650	160	30	40	230	70	25	95
		405	. Phenols	824 lbs/M$VA	1,000 lbs.	9,000	200	3,000	3,200	3,800	100	3,900	700	200	400	1,400	400	200	600
		358	. Cyanides	365 lbs./M$VA	1,000 lbs.	4,000	100	1,300	1,400	1,700	50	1,700	300	90	210	500	190	60	250
		359	. Fluorides	397 lbs. / M$VA	1,000 lbs.	4,000	100	1,300	1,400	1,700	50	1,700	300	90	210	600	190	60	250
		19	. Ammonia	997 lbs./M$VA	1,000 lbs.	11,000	400	3,600	4,000	4,600	200	4,800	850	230	600	1,700	500	200	700
		392	. Sulfuric Acid	40,473 lbs./M$VA	Million lbs.	450	10	150	160	190	--	190	35	10	25	70	20	10	30
		118	. Chromium	556 lbs./M$VA	1,000 lbs.	6,000	100	2,000	2,100	2,500	100	2,600	450	130	320	900	280	100	380
		419	. Zinc	.72 lbs./M$VA	1,000 lbs.	800	40	260	300	330	20	350	60	15	45	120	40	10	50
		212	. Hydrochloric Acid	1,718 lbs./M$VA	1,000 lbs.	13,000	800	6,200	7,000	7,900	350	8,200	1,400	400	1,100	2,900	900	300	1,200
	. Coke Plant		Raw Waste	3,000 gals./ton coal	Million gals	148,000	4,000	62,000	66,000	79,000	2,000	81,000	15,000	4,000	10,000	29,000	9,000	3,000	12,000
		405	. Phenol	0.55 lbs./ton coal	1,000 lbs.	35,000	800	11,000	12,000	15,000	400	15,000	2,700	800	1,900	5,400	1,600	600	2,200
		358	. Cyanide	0.32 lbs./ton coal	1,000 lbs.	20,000	400	6,600	7,000	8,400	300	8,600	1,600	400	1,100	3,100	900	400	1,300
		19	. Ammonia	0.35 lbs./ton coal	1,000 lbs.	22,000	700	7,300	8,000	9,200	300	9,500	1,700	500	1,200	3,400	1,000	400	1,400

Table III-6
(Continued)

WASTE SOURCE		WASTE TYPE		GENERAL QUANTIFICATION FACTORS	ANNUAL PRODUCTION OF HAZARDOUS WASTE QUANTITIES														
							NORTHEAST REGION			NORTH CENTRAL REGION			SOUTHERN REGION				WESTERN REGION		
SIC	DESCRIPTION	I.D.#	DESCRIPTION OF HAZARDOUS COMPOUNDS		UNITS	TOTAL U.S.	New England Division	Middle Atlantic Division	Total	E. North Central Division	W. North Central Division	Total	South Atlantic Division	E. South Central Division	W. South Central Division	Total	Mountain Division	Pacific Division	
	Blast Furnaces, Steel Works and Rolling and Finishing Mills (Continued)																		
	. Iron Manufacturing		**Raw Waste**	2,200 gals./ton product	Million gals.	158,000	4,000	1,500	5,500	65,000	2,000	67,000	12,000	3,300	8,700	24,000	7,300	2,700	10,000
		305	. Phenol	0.02 lbs./ton product	1,000 lbs.	1,000	100	300	400	400	--	400	80	20	60	160	50	10	60
		19	. Ammonia	0.25 lbs./ton product	100 lbs.	18,000	600	5,9000	6,500	7,500	300	7,800	1,400	400	1,000	2,800	800	300	1,100
		358	. Cyanide	0.09 lbs/ton product	1,000 lbs.	6,000	100	2,000	2,000	2,500	100	2,600	460	130	340	930	300	100	400
	. Cold Finishing		Finishing Waste	2,200 gals./ton product	Million lbs.	5,000	100	1,700	1,800	2,000	100	2,100	390	100	290	780	730	90	320
		358	. Cyanide	0.02 lbs./ton product	1,000 lbs.	61													
		198	. Iron	4.0 lbs./ton product	1,000 lbs.	10,000	200	3,300	3,500	4,200	100	4,300	800	200	600	1,600	470	130	600
		357	. Chromium (Total)	0.5 lbs./ton product	1,000 lbs.	1,000	100	300	400	400	--	400	80	20	60	160	50	10	60
		150	. Hexavalent Chromium	0.4 lbs./ton product	1,000 lbs.	1,000	100	300	400	400	--	400	80	20	60	160	50	10	60
		419	. Zinc	1.0 lbs./ton product	1,000 lbs.	2,000	100	700	800	830	30	860	160	40	120	310	90	30	120
	. Pickling		Rinse Water	500 gals./ton product	Million gals.	70,000	2,000	23,000	25,000	29,000	1,000	30,000	5,500	1,500	4,000	11,000	3,300	700	4,000
		212	. Hydrochloric Acid	2.5 lbs./ton product	Million lbs.	350	--	100	100	150	--	150	25	10	15	50	15	5	20
		382	. Sulfuric Acid	2.5 lbs./ton product	Million lbs.	350	--	100	100	150	--	150	25	10	15	50	15	5	20
			Pickle Liquor	199,000 lbs./M$VA	Million lbs.	218,000	4,000	72,000	76,000	91,000	3,000	94,000	17,000	4,600	11,400	34,000	10,000	4,000	14,000
		382	. Sulfuric Acid	40,000 lbs./M$VA	Million lbs.	450	10	150	160	190	--	190	35	10	25	70	20	10	30
		212	. Hydrochloric Acid	1,700 lbs./M$VA	1,000 lbs.	19,000	300	6,300	6,600	7,900	300	8,200	1,500	400	1,100	3,000	900	300	1,200
333	**Non-Ferrous Metals**																		
3334	. Aluminum		Primary Smelting Waste	--															
		359	. Fluoride	3 lbs./1,000 lbs. aluminum	1,000 lbs	30,000	2,100	600	2,700	6,600	300	6,900	6,000	1,000	6,000	13,000	7,200	200	7,400
			Plate and Sheet Waste																
		--	. Aluminum Phosphate	1.5 lbs./1,000 lbs. aluminum	1,000 lbs.	5,000	350	100	450	1,100	50	1,150	1,000	200	1,000	2,100	1,200	40	1,240
			Rinse Water and Pickle Liquor	200-1,000 gals./ton product	Million gals.	260 →1,300													
	. Brass Mill	126	. Copper	5 lbs./ton product	1,000 lbs.	12,000	400	3,400	3,800	100	3,100	3,200	700	300	300	1,300	900	2,900	3,800
		--	. Zinc	4 lbs./ton product	1,000 lbs.	10,000	200	2,900	3,100	30	2,600	2,600	600	250	250	1,100	800	2,400	3,200
		350	. Sodium Dichromate	5 lbs./ton product	1,000 lbs.	12,000	400	3,400	3,800	100	3,100	3,200	700	300	300	1,300	900	2,900	3,800
		382	. Sulfuric Acid	6 lbs./ton product	100 lbs.	14,000	400	4,000	4,400	300	3,400	3,700	800	300	300	1,500	3,300	1,100	4,400
			Bright Dip Liquor	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
		382	. Sulfuric Acid	80,000 ppm															
		126	. Copper	10,000 ppm															
		--	. Zinc	10,000 ppm															
		350	. Chromium	25,000 ppm															
34	**Fabricated Metal Products**																		
			Finishing Effluents	N.A.															
		124	. Copper	6 to 300 ppm															
		126																	
		196	. Iron	2 to 21 ppm															
		279	. Nickel	0 to 300 ppm															
		282																	
		419	. Zinc	0 to 300 ppm															

Table III-6
(Continued)

WASTE SOURCE		WASTE TYPE			ANNUAL PRODUCTION OF HAZARDOUS WASTE QUANTITIES														
							NORTHEAST REGION			NORTH CENTRAL REGION			SOUTHERN REGION				WESTERN REGION		
SIC	DESCRIPTION	I.D. #	DESCRIPTION OF HAZARDOUS COMPOUNDS	GENERAL QUANTIFICATION FACTORS	UNITS	TOTAL U.S.	New England Division	Middle Atlantic Division	Total	E. North Central Division	W. North Central Division	Total	South Atlantic Division	E. South Central Division	W. South Central Division	Total	Mountain Division	Pacific Division	Total
34	Fabricated Metal Products (Continued)																		
		350	. Hexavalent Chromium	0.5 to 700 ppm															
		358	. Cyanide	30 to 1,500 ppm															
			Plating Liquors	N. A.															
		279	. Nickel	82,000 ppm															
		282																	
	116	116	. Chromium	207,000 ppm															
		126	. Copper (Acid)	51,500 ppm															
		382	. - Sulfuric Acid	13,000 ppm															
		126	. Copper (Cyanide)	12,400 ppm															
		126	- Cyanide	28,000 ppm															
		--	. Copper (Pyrophosphate)	30,000 ppm															
		371	- Sodium Pyrophosphate	210,000 ppm															
		89	. Cadmium	23,000 ppm															
		89	- Cyanide	57,700 ppm															
		419	. Zinc	33,800 ppm															
		419	- Cyanide	48,900 ppm															
		363	- Caustic	38,000 ppm															
			. Brass																
		126	- Copper	21,000 ppm															
		419	- Zinc	5,250 ppm															
		126	- Cyanide	47,500 ppm															
		419																	
		376	. Tin	53,000 ppm															
		377																	
		364	. Silver (Cyanide)	24,600 ppm															
		364	- Cyanide	21,800 ppm															
80	Medical and Other Health Services																		
		--	Radioisotopes	1,000 lbs./yr./hospital in water 50 lbs./yr./hospital in solid															
		--	Drugs	1 lbs./bed/week as solid	1,000 lbs.	83,000			14,000			23,000				28,000			18,000
	Radioactive Waste		See Appendix																

- Cations (such as heavy metals) are referenced to the chloride or sulfate salt, unless a salt is more precisely identified. Example: often "copper" is reported in the literature; "copper sulfate" is referenced.

- Anions (such as cyanide or sulfide) are referenced to the sodium salt, unless more precisely identified.

- "Chromium" is referenced to "Chromic sulfate" or "sodium chromate," depending on the process, unless otherwise identified.

- "Phenols" are referenced to "phenol", unless a specific phenol derivative is noted.

- "Organic chlorides" are referenced to a prevalent component in the mixture that is indicated on the list of hazardous materials.

A continuing problem encountered in accomplishing this task is the scantiness of useful literature data. Even with an extensive survey such as this, lack of information is a limiting factor.

In some cases, specific constituent materials have been identified, but no quantification factors were given. So long as the identity was supplied, it has been included in the waste stream constituency listing of Table III-6, to provide a "second level" of hazardous material/waste stream correlation.

Table III-7 provides waste quantity data for the commercial explosives industry.

(2) Geographic Areas

In the preceding tables, the geographic areas have been limited to regions, rather than SMSAs and states. The regions indicated are standard U.S. regions as identified by the Bureau of the Census. The limitation of the waste streams and specific materials estimates to regions rather than smaller areas reflects the confidence place in the quantification factors which serve as the computational base. Again, it must be noted that whole

Table III-7
Distribution, Locations and Volumes of Explosive Manufacturing Wastes (1)

Federal Region	2	2	3	3	4	5	5	7	8	8	10
Quantities in pounds per day / Waste Material — Location	(S. E.) New York	New Jersey	E. Pennsylvania	W. Virginia	N. Alabama	S. Illinois	Ohio	S. Missouri	Utah	Colorado	Washington
Nitroglycerine & NG Mixtures	-	-	-	800	125	10	15	200	10	-	525
Cont. Waste Packaging	-	-	-	800	200	-	-	150	-	-	750
Combined Total	-	-	830	1600	325	10	15	1000	10	-	1275
Smokeless Powder	-	1000	-	-	-	-	-	-	-	-	-
Cont. Packaging	-	3	-	-	-	-	-	-	-	-	-
Combined Total	-	2003	-	-	-	-	-	-	-	-	-
Industrial Exp. & Prop.	-	20	125	-	-	100	-	-	50	-	-
Cont. Packaging	-	-	750	-	-	1000	-	-	250	-	-
Combined Total	-	20	1705	-	-	1100	-	48	300	-	-
Primer Materials & Caps	1	220	-	-	5	-	X	-	-	-	-
Cont. Packaging	1	650	-	-	2	-	-	-	-	-	-
Combined Total	2	870	415	-	7	-	X	-	-	5	-
Regional Total	2	3000	2950	1600	330	1110	15+	1050	310	5	1275

X - Materials detonated; quantity unspecified.

Notes: (1) Combined totals exceed sums of specified parts due to variance in reports from firms.

(2) This table represents reports from four major firms, only, and is not a complete inventory of rates of generation or locations; 6000 other plant operations are treated in a subsequent section.

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(1) Institute of Makers of Explosives, 420 Lexington Avenue, New York.

industries are being considered here, not individual plants, and the credibility limits of the approach taken are such that production of this type of estimates on a more localized basis is not justified. The results should be viewed as points of departure for future research rather than factual representations. Until reliable waste stream analyses are made at very specific locations, this situation will remain unchanged.

For future research purposes, it will be necessary to match the industries, according to SIC code, first to the states included in each region, then to specific plant locations, to determine the actual extent of production of the waste streams and specific materials contained.

The data availability problem is also demonstrated by the regional quantity data of Table III-6, in that the breakdown figures do not add up to the totals. The reasons are that:

- Independent estimates were made for waste streams, compounds, and regional totals, based on Census of Manufactures production data
- In several cases, production data is not available in the Census of Manufactures
- Some errors result from data interpretation
- Some errors result from rounding-off in a series of computations.

Since only a limited number of hazardous materials (by name) could be correlated with waste streams, there remains the problem of assisting future research efforts by providing some form of correlation that will at least aid in directing those efforts toward the appropriate industry sectors. This is discussed in the following section.

5. HAZARDOUS MATERIALS EXPECTED IN NONIDENTIFIABLE WASTE STREAMS OF INDUSTRIAL MANUFACTURERS AND USERS

The preceding tables have listed, to the extent possible based on literature data, the hazardous materials expected to appear in specifically identifiable waste streams where certain manufacturing processes and commonly named waste streams are known, and provide waste quantity estimates where waste stream makeup has been reported in literature.

The literature data base is severely limited however, and there remain many hazardous materials that can reasonably be expected to be included in industrial waste streams, but where waste streams are not identifiable by common names from the literature. Further, waste generation rates, waste stream constituency and waste concentrations could not be documented, even though the literature data bank developed in this study is considered comprehensive. Direct correlation with specific waste streams, then, cannot be made. Rather, it can only be surmised that since certain industry groups are known principal manufacturers and users of the hazardous materials, the materials will appear in one or more of these industries' general waste streams.

It is important as a minimum, therefore, to correlate the remaining hazardous materials with the industry groups as specifically as possible. In this way, useful information is provided which serves as guidance in identification and direction of needed further research related to the occurrence and quantification of hazardous materials in mixed waste streams. Since the locations of specific industry segments (plants) can be identified, research efforts can be directed toward determination of specific materials' manufacture and use, and thus potential point sources of hazardous wastes can be identified.

Table III-8 lists the hazardous materials for which neither waste stream data nor quantifiaction data are available, and correlates those materials with SIC codes. Where a substance is heavily used or produced by a particular sector, specific codes, to the four-digit level, are given. Otherwise, two- or three-digit SIC reference is given. The inference is that these materials will be found in the general waste streams from those industry groups, and that further detailed research is needed to determine whether hazardous conditions are generated and the precise nature of such conditions.

Table III-8
Hazardous Materials Expected in Waste Streams of Producers and Users

I. D. Num.	Substance (Common) Name	Standard Industrial Code Significant Manufacturer and/or User	
		Producer	User
3	Acetic Anhydride	2818	20, 26, 2818, 282, 36
4	Acetone	2818	28, 38
5	Acetone Cyanhydrin	2818	28
6	Acetonitrile (Methyl Cyanide)	2818	28
7	Acetyl Chloride	2818	20, 28
8	Acetylene	2813	28, 34
9	Acridine	2818	28
10	Acrolein	2818, 291	19, 28
11	Acrylic Acid	2818	22, 26, 28, 31
13	Aldrin	2818, 291	28
15	Allyl Chloride	2818	28
16	Aluminum Flouride	2819	20, 28, 32, 33
17	Aluminum Oxide	3291	28, 32
18	Aluminum Sulfate	10, 14, 2819	20, 22, 26, 31, 49
20	Ammonium Chloride	2819	20, 28, 3692
21	Ammonium Chromate	2819	22, 38
22	Ammonium Dichromate	2819	27, 28, 32, 38
23	Ammonium Flouride	2819	20, 22, 24, 28, 32
25	Ammonium Perchlorate	2819	28
26	Ammonium Persulfate	2819	20, 28, 34, 38
27	Ammonium Picrate (Dry)	2819	28
28	Ammonium Picrate (Wet)	2819	28
30	Amyl Acetate (Banana Oil)	2818	20, 22, 28, 39
32	Aniline	2815	2815, 2818, 30, 38
33	Anthracenes	2815	28
34	Antimony	3339	22, 28, 30, 32, 33
35	Antimony Pentachloride	2819	28
36	Antimony Pentafluouride	2819	28
37	Antimony Pentasulfide	2819	28, 30, 39
38	Antimony Potassium Tartrate	2819	28
39	Antimony Sulfate	2819	28, 39
40	Antimony Sulfide	2819	28, 38, 39
41	Antimony Triethyl (Triethylstirine)	2819	28
42	Antimony Trichloride	2819	28, 32
43	Antimony Trifluouride	2819	28, 32
44	Antimony Trimethyl (Trimethylstirine)	2819	28
45	Antimony Trioxide	2819	28
46	Arsenic	3339	28, 311
47	Arsenic Chloride	2819	28
48	Arsenic Diethyl	2819	28
49	Arsenic Dimethyl	2819	28
50	Arsenic Pentaselenide	2819	32
51	Arsenic Trichloride	2819	28, 32
52	Arsenic Trioxide	2819	22, 28, 31, 33
54	Barium Carbonate	2819	28, 32, 33
55	Barium Chloride	2819	28
56	Barium Cyanide	2819	28, 34
57	Barium Fluoride	2819	28, 32, 36
58	Barium Nitrate	2819	28, 36, 39
59	Barium Sulfide	2819	28, 30
61	Benzene Hexachloride	2815	28

Table III-8
(Continued)

I. D. Num.	Substance (Common) Name	Standard Industrial Code Significant Manufacturer and/or User Producer	 User
62	Benzene Sulfonic Acid	2815	28
63	Benzoic Acid	2815	28, 38
64	Benzyl Chloride	2815	28
65	Beryllium Carbonate	2819	33
66	Beryllium Chloride	2819	28
67	Beryllium Hydroxide	2819	28
68	Beryllium Oxide	2819	28, 32
69	Beryllium Powder	3339	33, 36
70	Beryllium Selenate	2819	28
71	Boron Trichloride	2819	28, 33
72	Boron Trifluouride	2819	28, 33
73	Bromic Acid	2819	28
74	Bromine	2819	28
75	Bromine Pentafluouride	2819	28
77	Butane	2818	23, 29
79	Butene - 1 (Ethyl Ethylene)	2818	28
80	Butylacetate (Butyl Ethanoate)	2818	22, 26, 28
81	Butylacrylate	2818	28, 30
82	N-Butylamine	2818	28
83	Butyl Mercaptan	2818	28
84	Butyl Phenol	2818	28
86	Cacodylic Acid (Dimethylarsinic Acid)	2818	28
87	Cadmium	3339	28, 34
90	Cadmium Fluoride	2819	36
91	Cadmium Nitrate	2819	28
92	Cadmium Oxide	2819	28, 30, 32, 33
93	Cadmium Phosphate	2819	28
94	Cadmium Potassium Cyanide	2819	28, 347
95	Cadmium Sulfate	2819	28, 36
96	Calcium Arsenate	2819	28
97	Calcium Arsenide	2819	28, 33
98	Calcium Carbide	2819	22, 28
99	Calcium Cyanide	2819	28
101	Calcium Hydride	2819	28
102	Calcium Hydrochlorite	2819	28
104	Carbon Disulfide	2818	2823
105	Carbon Monoxide		20, 28, 33
107	Carbon Chloride (Phosgene)	2818	
108	Chloral Hydrate	2818	28
110	Chlorine Trifluoride	2812	28
111	Chloroacetophenone	2818	29
113	Chlorodene	2818	28
115	Chlorosulfonic Acid	2818	28
117	Chromic Flucuride	2819	22, 28, 32, 34
119	Chromium Cyanide	2819	28, 3471
120	Coal (Particle)		29
122	Cobaltous Nitrate	2819	28, 32
123	Copper Acetoarsenite	2819	24, 28
127	Creosote	2815, 2861	24, 28
128	Cresol (Cresylic Acid)	2821	20, 28, 33

Table III-8
(Continued)

I. D. Num.	Substance (Common) Name	Standard Industrial Code Significant Manufacturer and/or User	
		Producer	User
129	Crotonaldehyde	2818	20, 28
130	Cumene (Isopropylbenzol)	2818	28
132	Cyanoacetic Acid	2818	28
133	Cyclohexane (Hexanhydrobenzene)	2815	28
134	Cyclohexanol (Hexalin)	2818	28
135	Cyclohexanone	2818	28
136	Cyclohexylamine	2818	30
137	Demeton	2818	28
138	Decyl Alcohol	2818	28
139	Dibutyl Pathalate-n	2818	28
140	o-Dichlorobenzene	2818	28
141	p-Dichlorobenzene	2818	28
142	2, 4-Dichlorophenoxyacetic Acid (2, 4-D)	2842, 2879	28
143	DDD (Dichloro Diphenyl Dichloro Ethene)	2842, 2879	28
144	DDT (Dichloro Diphonyl-Trichloroethane)	2842, 2879	28
145	Diborane (Boron Hydride)	2819	28
146	Dichloroethyl Ether	2818	28
148	1, 2-Dichloropropane	2818	28
149	1, 3-Dichloropropene	2818	28
150	Dieldrin	2818	28
151	Diethanolamine	2818	28
152	Diethylamine	2818	28, 29, 30
153	Diethyl Ether (Ethyl Ether)	2818	28
154	Diethylene Dioxide (1, 4-Dioxane)	2818	28
155	Diethylene Triamine	2818	28
156	Diethylotilbestrol	2818	28
157	Diisobutylene	2818	28
158	Diisobutyl Ketone	2818	28
159	Dimethylamine	2818	28
160	Dimethyl Sulfate (Methyl Sulfate)	2818	26, 26, 29
161	2, 4-Dinitroaniline	2818	28, 34
163	o-Dinitrobenzol (1, 2-Dinitrobenzene)	2818	28
164	2, 4-Dinitrophenol	2818	28, 34
165	2, 4-Dinitrotoluene (Dinitrotoluol)	2818	28
166	Diphenylamine (Phenylaniline)	2815	28
167	Dipropylene Glycol	2818	28
168	Dodecyl Benzene (Crude)	2818	28
169	Endrin	2818	28
170	Epichlorohydrin	2818	20, 28
171	Ethane	2818	28
173	Ethanolamine (Monoethanolamine)	2818	22, 28, 29, 31
174	Ethers	2818	28
175	Ethyl Acetate (Acetic Ether)	2818	28
176	Ethyl Acrylate	2818	22, 26, 28, 31
177	Ethylamine (Monoethylamine)	2818	20, 28
179	Ethyl Chloride (Chloroethane)	2818	28
180	Ethylene (Ethene)	2818	28
181	Ethylene Bromide (Ethylene Dibromide)	2818	28, 29
182	Ethylene Cyanohydrin	2818	28
183	Ethylene Diamine	2818	28

Table III-8
(Continued)

I. D. Num.	Substance (Common) Name	Standard Industrial Code Significant Manufacturer and/or User	
		Producer	User
184	Ethylene Diapomide (Dibromethane)	2818	28
186	Ethylene Glycol (Glycol)	2818	28
187	Ethylene Glycol Monoethyl Ether	2818	28
190	Ethylenimine	2818	22, 26, 28, 34
191	2-Ethylhexamol (Octyl Alcohol)	2818	28
193	Ethyl Methyl Ketone (Butanone)	2818	28
194	Ethyl Phthalate (Diethyl O-Phthalate)	2818	28
195	2-Ethyl-3Propyl Acrolein	2818	28
197	Fluorides (e.g., Hydrogen Fluoride, etc.)	2819	28
198	Fluorine (Hydrofluoric Acid)	2819	28
202	Furfural Alcohol	2818	28
203	Guthion	2818	28
204	Heptalchor	2818	28
205	Heptane (Heptyl Hydride)	2818	28
206	Hexachlorophene (Methylene)	2818	28
207	Hexaethyltetraphosphate	2818	34, 38
208	Hexamethylene Diamine	2818	28, 34
209	Hexane (Hexyl Hydride)	2818	28
210	Hydrazine (Anhydrous Diamine)	2818	28
211	Hydrobromic Acid	2819	28
213	Hydrocyanic Acid (Hydrogen Cyanide)	2819	28, 33, 34
214	Hydrofluoric Acid (Hydrogen Fluoride)	2819	28, 29, 33, 34
215	Hydrogen Chloride Anhydrous	2819	28
217	p-Hydroquinone	2815	28, 34
219	Iodine	2819	2834
220	Isobutyl Acetate	2818	2821, 34
222	Isophorone	2818	28
223	Isoprene	2822	28, 30
225	Isopropyl Acetate	2818	28
226	Isopropyl Amine	2818	28
227	Isopropyl Ether	2818	22, 28
229	Lead Acetate	2819	28
230	Lead Arsenate	2819	2879
231	Lead Arsenite	2819	28
232	Lead Carbonate	2819	28
233	Lead Chlorite	2819	18
236	Lead Nitrite	2819	28
237	Lead Oxide	2819	2816, 30, 32
238	Lithium Aluminum Hydride	2819	28
239	Magnesiumo-arsenite	2819	28
240	Magnesium Chlorate	2819	28
241	Magnesium Sulfate	2819	22, 26, 28, 31, 32, 36
243	Manganese	3339	28, 3295, 3313, 34
244	Manganese Arsenate	2819	28
245	Manganese Chloride	2819	22, 28, 35, 36
246	Manganese Cyclorentadiehyltricarbonyl	2818	28
248	Mercuric Cyanide	2819	28, 38
249	Mercuric Diammonium Chloride	2819	28
250	Mercuric Nitrate	2819	28
251	Mercuric Sulfate	2819	28, 33, 36

Table III-8
(Continued)

I. D. Num.	Substance (Common) Name	Standard Industrial Code Significant Manufacturer and/or User	
		Producer	User
254	Mesityl Oxide	2818	28
256	Methyl Acetate	2818	28
257	Methyl Acrylate (Acrylic Esters)	2818	28, 31
258	Methylamine (30 Percent Solution)	2818	28, 30
260	Methyl Bromide (Bromomethane)	2818	28
261	Methyl Chloride (Chloromethane)	2818	28, 30
262	Methyl Chloroformate	2818	28
263	Methyl Formate (Methyl Methanoate)	2818	26
266	Methyl Methacrylate Monomer	2818	28, 29
267	Methyl Parathton	2818	28
268	Monomethylamiline (n-Methylanilins)	2818	28
269	Morpholine	2818	28, 30, 34
270	Naphtha (Crude)	2911	2815,
271	Naphthalene (Naphthaline)	2815	28, 31, 34
272	Naphthylamine-beta	2815	28
273	Nickel	3339	28, 33, 34
274	Nickel Ammonium Sulfate	2819	28, 34
275	Nickel Antimonide	2819	28, 34
276	Nickel Arsenide	2819	32
277	Nickel Carbonyl	2819	28
280	Nickel Nitrate	2819	28, 32, 34
281	Nickel Selenide	2819	36
284	Nitroamilene (Nitraneline-meta-para)	2815	28
285	Nitrobenzene (Nitrobenzol)	2815	28
286	Nitrochlorobenzine (meta or para)	2815	28, 30
287	Nitroethane	2818	28
288	Nitroglycerin	2897	19, 28
289	Nitromethane	2818	29
290	Nitroparaffins	2815	19, 28
291	p-Nitrophenol	2815	2818, 34
292	Nitropropane (1 and 2)	2818	28
294	Nitrous Oxide	2813	20, 28
295	Oxalic Acid	2818	22, 28, 31
296	Paraformaldehyde	2818	28
297	Parathion	2818	2879
298	Pentaropane	2819	28
299	Pentachlorophenol	2818	22, 24, 26, 28
300	PETN (Pentafrythritol Tetranitrate)	2818	19, 28
301	n-Pentane (Amyl Hydride)	2818	28, 38
302	Perchloric Acid (72 Percent Solution)	2819	28
303	Perchloroethylene (Tetrachloroethylene)	2818	22, 38
304	Perchloryl Fluoride	2818	28
306	Phenylhydrogine Hydrochlorine	2818	28
308	Phosphorus (Red)	2819	22, 28
310	Phosphorus Oxychloride	2819	28, 29
311	Phosphorus Pentachloride	2819	28
312	Phosphorus Pehtasulfide	2819	28, 29
313	Phosphorus Trichloride	2819	28, 33
315	Picric Acid (Trinetrophenol)	2818	19, 28
317	Potassium Arsenite	2819	28, 32
318	Potassium Pinoxalate	2819	28, 34
319	Potassium Chromate	2819	28

Table III-8
(Continued)

I. D. Num.	Substance (Common) Name	Standard Industrial Code Significant Manufacturer and/or User	
		Producer	User
320	Potassium Cyanide (Solid)	2819	10, 28, 33, 34
321	Potassium Dichromate	2819	22, 26, 27, 28, 29, 31
322	Potassium Fluoride	2819	20, 28, 32
323	Potassium Hydroxide (Caustic Potash)	2819	28
324	Potassium Oxalate	2819	28, 34
325	Potassium Permanganate	2819	22, 28, 31, 38
326	Potassium Peroxide	2819	28
327	Potassium Sulfate	2819	28
328	Potassium Sulfide	2819	28, 30, 33, 34, 35, 39
329	Propane (L. P. Gas)	2815	28, 29
330	Propionaldehyde (Propyl Aldehyde)	2818	28, 30, 32
331	Propionic Acid	2818	28
332	n-Propyl Acetate	2818	20, 28
333	n-Propyl Alcohol	2818	28
334	Propylamine	2818	28
335	Propylene	2818	28, 29
337	Propylene Oxide	2818	28
338	Propylene Dichloride (Dichloropropane)	2818	20, 28
339	Pyridine	2818, 2815	2822, 30
340	Quinone	2818	28, 34
341	Salicylic Acid	2818	2833, 30
342	Selenium Powder	3339	19, 30, 32, 33, 36
343	Silicon Tetrachloride	2819	19, 28
345	Sodium	3339	28, 33
346	Sodium Amide (Sodamide)	2819	28
347	Sodium Arsenate	2819	22, 28
348	Sodium Arsenite	2819	2879
349	Sodium Azide	2819	19, 28
351	Sodium Bisulfite	2819	20, 26, 28
352	Sodium Borate	2819	28, 32, 33
353	Sodium Cacodylate	2818	28
355	Sodium Carbonate Peroxide	2819	26, 28
356	Sodium Chlorate	2819	26, 28
360	Sodium Formate	2819	28
361	Sodium Hydride (Crystals)	2819	28
362	Sodium Hydrosulfite	2819	22, 28
364	Sodium Iodide	2819	28
367	Sodium Oxalate	2819	28
368	Sodium Oxide	2819	28
369	Sodium Perchlorate	2819	19
370	Sodium Peroxide	2819	28
372	Sodium Potassium Alloy	2819	28
375	Sodium Thiocyanate (Sodium Sulfcyanide)	2819	28
378	Strontium	3339	28, 29, 32
381	Sulfur Trioxide	2819	19, 28
383	Sulfurous Acid	2819	28
384	Sulfuryl Fluoride	2819	28
385	Tantalum	3339	28, 33
387	Tear Gas (CN)	2819	19

Table III-8
(Continued)

I. D. Num.	Substance (Common) Name	Standard Industrial Code Significant Manufacturer and/or User — Producer	User
388	Tetrachloroethane (Acetylenetetrachloride)	2818	28
389	Tetraethyl Lead	2818	29
390	Tetrahydrofuran	2818	28
391	Tetramethyl Lead	2818	29
392	Tetranitromethane	2818	19
393	Thallium	3339	28, 33, 34
395	Titanium Tetrachloride	2819	28
397	Toluene Diisocyanate	2815	28, 29
398	Toluidine-o (2,4-Methylanilene)	2815	22, 28
401	Trichloroethylene	2818	22, 28, 34
402	Trichlorofluoromethane (Freon 11)	2818	28
403	Triethanolamine	2818	28, 32
404	Triethylamine	2818	28
405	Triethylene Glycol	2818	28, 29
406	Triethylene Tetramine	2818	28
407	Trimethylamine	2818	28
408	Tri-o-Cresyl Phosphate	2818	28, 29, 35
409	Turrentine	2861	28
410	Vanadium Pentoxide	2819	22, 28, 32, 38
411	Vanadium Sulfide	2819	28, 32
414	m-Xylene (Xylox)	2815	28
415	Xylenol (3, 5-Dimethylphenol)	2815	28
416	Zinc Arsenate	2819	28
417	Zinc Arsenite	2819	28
420	Zinc Nitrate	2819	22, 28
421	Zinc Oxide	2819, 2816	20, 22, 28, 30, 32, 34
422	Zinc Permanganate	2819	28
423	Zinc Peroxide	2819	28

6. HAZARDOUS MATERIAL WASTE QUANTITIES REPORTED BY DEPARTMENT OF DEFENSE AND ATOMIC ENERGY COMMISSION

Both the Department of Defense (DoD) and the Atomic Energy Commission (AEC) have long been concerned with control and disposal materials, especially those peculiar to their operations. While neither has solved the disposal problems, each has exercised control systems which generally prevent discharge of hazardous materials to the environment, and the reports included in the control systems allow these agencies to maintain awareness of the magnitude of their problems.

The tables which follow present data extracted from those reporting systems. Table III-9 presents quantities of various DoD hazardous waste in inventory. It should be noted that, with respect to pesticides, herbicides, and related items, the materials awaiting disposal are at bases scattered across the nation and throughout the world. However, it is expected that all overseas quantities would be returned to the U.S. for disposal. Additional listings of hazardous chemicals (but without quantity data) associated with DoD activities are provided in Chapter IV (see Tables IV-20, IV-21, IV-22 and IV-23 on pages IV-44 through IV-48). Further information regarding the total DoD waste picture is presented in Appendix A-13. Table III-10(a) summarizes waste quantity data for radioactive materials under the control of the AEC. Tables III-10(b), (c), and (d) provide details of the data summarized in Table III-10(a), and include names of the specific radioactive waste constituent materials, along with energy levels in Curies. These data are supported by descriptive information contained in Appendix A-12.

7. MINING INDUSTRY WASTES

Extensive data has been developed on the solid wastes generated by the mining industries. A summary is included to provide an overview of the total solid wastes which are generated in the mining industry, and to provide a brief appraisal of the contributions of these wastes to environmental effects. Additional data are contained in Appendix A-1.

Table III-9

Hazardous Waste Material Quantities Reported by the Department of Defense as Awaiting Disposal

	Material	Quantity
1.	Pesticides, Herbicides and Related Items (e.g., insect repellant)	2,887,200 lbs. (in powder form) 1.736,800 gal. (Liquid)
2.	Explosive Munitions (projectiles, small arms ammunition, bombs, rockets, etc.)	80,000 - 12,000 Tons
3.	Chemical Munitions:	
	Mustard	3,071 tons
	GB	2,085 tons
	Phosgene	2,700 tons
4.	Chemical Munitions Manufacturing Wastes:(1)	
	Liquid Waste Stored in Lagoons	129,000,000 gal. (7.5-8.0% salts)
	Contaminated Soil	12,000,000,000 cu.ft.
	Suspended solids of phosphorus and phosphorous oxides	200,000,000 gal.
	DOD-Supplied Waste Generation and Disposal Data (Examples)	
5.	Waste Petroleum Products:	
	Accumulated and disposed of through Defense Supply Agency	77,500 gal. /yr.
	Accumulated and disposed of by the Air Force (90 bases)	9,600,000 gal. /yr.
	Estimated totals for other services (Army, Navy, Marine Corps)	10,000,000 gal. /yr.

(1) Also reported unknown, but substantial, quantities of sludges containing dyes, sulfur, magnesium, aluminum, etc.

Table III-10(a)
Radioactive Waste Quantities Reported by Atomic Energy Commission, With Projections

1. Power Reactor Wastes (in Cubic Feet)

	1970	1975	1980
Solid	120	2,300	13,500
Liquid	30,000	170,000	330,000

2. Fuel Reprocessing Wastes (Accumulation)

	1970	1980	1990
If Solid (cu. ft.)	170	44,000	240,000
If Liquid (gal.)	17,000	4,400,000	24,000,000

3. Fuel Reprocessing Wastes (Generation Rates)

	1970	1980	1990
If Solid (cu. ft.)	170	9,700	27,000
If Liquid (gal.)	17,000	970,000	2,700,000

4. Miscellaneous Solid Wastes (Generation Rates in Cubic Feet)

1970	1975	1980
51,000	256,000	675,000

5. Cladding, Hulls, and Hardware (Generation Rates in Cubic Feet)(1)

1970	1975	1980
	6,100	11,500

(1) Accumulation expected to be 40,000 cu. ft. by 1980.

Table III-10(b)

Solid Waste from Power Reactors to Land Burial (Curies)

Radio-nuclide	1970		1975		1980	
	Resin and Sol. Liquids	Control Rods	Resin and Sol. Liquids	Control Rods	Resin and Sol. Liquids	Control Rods
H-3	1.4×10^{2}	1.3×10^{3}	2.3×10^{3}	7.0×10^{4}	6.8×10^{3}	3.4×10^{5}
Mn-54	2.7×10^{1}	1.8×10^{3}	4.2×10^{2}	1.0×10^{5}	1.3×10^{3}	2.5×10^{5}
Fe-55	9.7×10^{2}	5.6×10^{4}	1.5×10^{4}	3.0×10^{6}	4.5×10^{4}	8.0×10^{6}
Fe-59	-	-	4.6	-	1.4×10^{1}	-
Co-58	6.6×10^{1}	2.0×10^{2}	1.0×10^{3}	1.2×10^{4}	3.0×10^{3}	2.9×10^{4}
Co-60	4.6×10^{2}	7.0	6.4×10^{3}	3.5×10^{2}	1.7×10^{4}	8.4×10^{2}
Ni-59	-	7.0	-	3.5×10^{2}	-	8.4×10^{2}
Ni-63	1.2×10^{2}	1.0×10^{3}	1.8×10^{3}	5.4×10^{4}	4.6×10^{3}	1.3×10^{5}
Sr-89	5.8	-	1.1×10^{1}	-	3.0×10^{2}	-
Sr-90	2.4	-	4.4×10^{1}	-	1.3×10^{2}	-
Zr-95	1.7	-	2.8×10^{1}	-	8.1×10^{1}	-
Nb-95	3.6	-	6.0×10^{1}	-	1.7×10^{2}	-
Ru-103	6.8×10^{1}	-	1.2×10^{3}	-	3.5×10^{3}	-
Ru-106	1.6×10^{3}	-	2.8×10^{4}	-	7.9×10^{4}	-
Ag-108	-	1.1×10^{3}	-	6.0×10^{4}	-	4.0×10^{5}
Ag-110	-	3.9×10^{4}	-	2.1×10^{6}	-	1.3×10^{7}
Cd-109	-	1.8×10^{2}	-	1.0×10^{4}	-	6.0×10^{4}
Cd-115	-	7.0	-	4.0×10^{2}	-	1.8×10^{3}
In-114	-	2.0	-	1.2×10^{2}	-	8.0×10^{2}
Cs-134	2.3×10^{2}	-	3.8×10^{3}	-	1.1×10^{4}	-
Cs-137	8.3×10^{2}	-	1.4×10^{4}	-	4.1×10^{4}	-
Ce-141	-	-	2.0	-	6.0	-
Ce-144	7.5	-	1.4×10^{2}	-	4.0×10^{2}	-
Total Ci	4.4×10^{3}	1.0×10^{5}	7.4×10^{4}	5.4×10^{6}	2.1×10^{5}	2.2×10^{7}
Tot. cu. ft.	3.0×10^{4}	1.2×10^{2}	1.7×10^{5}	2.3×10^{3}	3.3×10^{5}	1.35×10^{4}

Table III-10(c)
Forecast of the Generation Rates and the Total Accumulations of Long-Life Fission Products and Actinides in High-Level Wastes from Fuel Reprocessing[(e)]

Isotopes	Generation Rate[(c, d)] (curies/year)			Accumulation (curies)		
	1970	1980	1990	1970	1980	1990
H-3	4.0×10^{4}	2.1×10^{6}	6.2×10^{6}	4.0×10^{4}	7.3×10^{6}	3.6×10^{7}
Kr-85	6.0×10^{5}	3.3×10^{7}	9.0×10^{7}	6.0×10^{5}	1.2×10^{8}	5.7×10^{8}
1-129	2.0	1.1×10^{2}	4.4×10^{2}	2.0	4.8×10^{2}	2.7×10^{3}
As High Level Liquid or Solid Wastes						
Sr 90	4.0×10^{6}	2.3×10^{8}	5.6×10^{8}	4.0×10^{6}	9.6×10^{8}	4.6×10^{9}
C 137	5.6×10^{6}	3.2×10^{8}	8.8×10^{8}	5.6×10^{6}	1.3×10^{9}	6.5×10^{9}
Pu 238	7.0×10^{2}	4.1×10^{4}	2.0×10^{5}	7.0×10^{2}	1.2×10^{6}	8.3×10^{6}
Pu 239	9.0×10^{1}	5.0×10^{3}	5.0×10^{4}	9.0×10^{1}	2.0×10^{4}	2.4×10^{5}
Pu 240	1.2×10^{2}	7.0×10^{3}	6.0×10^{4}	1.2×10^{2}	4.0×10^{4}	4.0×10^{5}
Am 241	9.0×10^{3}	5.0×10^{5}	4.4×10^{6}	9.0×10^{3}	2.3×10^{6}	2.3×10^{7}
Am 243	2.1×10^{2}	1.0×10^{4}	1.0×10^{5}	2.1×10^{2}	2.3×10^{5}	1.5×10^{6}
Cm 244	1.3×10^{5}	7.4×10^{6}	1.8×10^{7}	1.3×10^{5}	3.0×10^{7}	1.4×10^{8}
Gals/yr if liq.[(a)]	1.7×10^{4}	9.7×10^{5}	2.7×10^{6}	1.7×10^{4}	4.4×10^{6}	2.4×10^{7}
Cu ft/yr if sol.[(b)]	1.7×10^{2}	9.7×10^{3}	2.7×10^{4}	1.7×10^{2}	4.4×10^{4}	2.4×10^{5}

(a) Assumes 100 gallons per 10,000 Mwd.
(b) Assumes 1 cu ft per 10,000 Mwd.
(c) Assumes LWR @ 33,000 Mwd/MTU, 30 Mw/MTU, 90d. clg; LMFBR @ 80,000 Mwd/Mtu, 148 Mw/MTU 30d. clg.
(d) Assumes 0.5% of Pu to waste.
(e) Assumes introduction of LMFBR in 1980.

Table III-10(d)
Generation of Miscellaneous Solid Waste and Hulls and Hardware at Fuel Reprocessing Plants

	1970	1975	1980
Purex			
Miscellaneous Waste - ft^3	5.1×10^4	2.2×10^5	6.3×10^5
- Ci	5.2×10^4	2.3×10^5	7.8×10^5
Cladding - ft^3	-	2.4×10^3	6.7×10^3
- Ci	-	6.5×10^6	1.8×10^7
Aquafluor			
Miscellaneous Waste - ft^3	-	3.6×10^4	4.5×10^4
- Ci	-	3.7×10^4	5.6×10^4
Cladding - ft^3	-	3.7×10^2	4.8×10^2
- Ci	-	1.0×10^6	1.3×10^6

The total accumulation of cladding hulls and hardware by 1980 is estimated to be 40,000 cubic feet.

The amount of solid wastes generated by the mining and smelting industries is great in comparison to the wastes generated by other industrial sectors. These wastes add toxic compounds to the streams and rivers which may be hazardous to aquatic life. Once introduced into water, acids and salts contribute to the general lowering of water quality which results from major waste flows.

The residual solid wastes range from slightly radioactive granular wastes from uranium extraction, to the thick slimes which remain when phosphates are extracted.

The following paragraphs discuss, in general, the pollutant causes and effects, and the magnitude of accumulated wastes attributed to the activities of the Mineral Mining Industry. The pollutants are discussed as to their effects on land, water, and air. (More details are given in Appendix A-1).

(1) Land Pollution

Solid wastes are generally produced as the rejected material from mining, processing, and smelting operations. It is estimated that accumulated solid wastes from this industry now amount to 23 billion tons, covering an estimated 1.8 billion acres of land surface. Approximately 95 percent of this waste covered acreage is due to the production of coal, sand and gravel, stone, gold, clay, phosphate and iron. Table III-11 gives a breakdown of the tonnage and surface area covered by accumulated wastes. In addition, it provides a general indication as to areas of concentration of these wastes and the portion contributed by each mineral type.

The results of mining solid wastes accumulation is to denude land, change surface and subsurface drainage patterns, abet flooding, clog stream channels, pollute water and air, provide potential waste ban fires, and cause land-use conflicts.

(2) Water Pollution

Today only about one percent of an estimated 99,000 billion gallons of water used domestically is required by the mineral industry. However, pollution resulting from decades

Table III-11
Tonnage and Acreage of Accumulated Mineral Wastes (1968)

Mineral	Million Tons	Acres	Solid Waste Location
Antimony	.5	20	Idaho
Asbestos	35.4	222	Cal., Vt.
Barite	111.4	1,001	Ga., Mo., Tenn., Cal., Nev., Mont.
Bauxite	23.8	134	Ark.
Beryllium	.8	200	S.D.
Boron	76.0	600	Cal.
Clay	27.2	600	Cal., Ga.
Coal	1,493.7	Unknown	26 States - Va., Pa., Ind., Ala., Ky. (81%)
Copper	11,332.3	52,806	14 States - Ariz., Mont., Nev., Utah (88%)
Diatomite	75.5	825	Cal., N.H.
Feldspar	9.9	526	N.C., S.D., Ca.
Fluorspar	7.8	510	Col., Ill., N. Mex.
Gold	728.1	10,883	11 States - Alaska, Cal., Nev., S.D. (Principal)
Gypsum	20.3	140	Cal., Nev.
Iron - Steel	2,156.8	13,996	23 States
Lead-Zinc-Silver	1,476.3	28,652	14 States
Magnesite	22.0	290	Nev., Wash.
Manganese	15.9	805	Ariz., Cal., Mont., Nev., N. Mex.
Mercury	24.3	620	Ariz., Cal., Idaho
Mica	5.4	45	N.C. (Idaho Unknown)
Molybdenum	317.5	1,165.4	Col., N. Mex.
Misc.	2,434.4	25,147.0	28 States
Nickel	11.5	15	Nev.
Potash	233.8	1,143	N. Mex.
Phosphate	616.5	9,858	16 States - Fla. (Principal)

Table III-11
(Continued)

Mineral	Million Tons	Acres	Solid Waste Location
Stone	313.3	3,603	12 States - Pa., Cal. (Principal)
Tungsten	27.5	955	Ark., Cal., Col., Idaho, Mont., Nev.
Talc	2.7	31	Cal., Nev., Vt.
Titanium	74.2	417	N.Y., Va.
Vermiculi	12.0	20	Mont.
Total	21,686.6	154,674*	

* Coal area not included.

of mining activity has produced damaging environmental conditions in almost every major freshwater course or lake in the country. Industrial pollutants into water are of three types: (1) physical, (2) chemical, and (3) a combination of both. The following breakdown is given to indicate the extent to which our water resources have been affected by pollution, and the acreage of wildlife habitat that has been degraded as a result of this pollution.

- Stream—An estimated 12,989 miles of streams covering approximately 135,970 acres of land area, have been adversely affected by mineral wastes. The problem affects 40 states, with Pennsylvania, Louisiana, and Ohio, respectively, showing the greatest amount of degradation.

- Lakes—A total of 281 lakes, covering a land area of approximately 103,630 acres in seven states, have the bulk of this contamination. These are Louisiana, Minnesota, and Michigan, respectively.

- Reservoirs and Impoundments—A total of 168 such installations covering 41,516 surface acres of water throughout 18 states show this contamination. The preponderance of this pollution is found in Alabama, South Dakota, Missouri, West Virginia, and Pennsylvania, in that order.

- Wildlife Habitat—Approximately 1,617,288 acres of wildlife habitat in 46 states have been adversely affected. Pennsylvania, West Virginia, Texas, Indiana, and Illinois, in that order, show the greatest degree of degradation.

(3) Air Pollution

The common forms of air pollution are well known to most people. Approximately 86 percent of the total of this type pollution is contributed by the production, processing, use, and disposal of minerals and fossil fuels. Dust and gaseous emissions are the principal elements in its production. The origin and effects of these elements on the environment are briefly discussed below:

- Dust—The causes of dust in the atmosphere include the following:
  - Blasting, loading, hauling, crushing, and processing of ore
  - Drying of settling and tailings ponds, and poor waste bank site selection
  - Failure to properly dispose fine waste material
  - Burning of fossil fuels and combustible waste
  - Failure to use chemical soil stabilizers.

  The degrading of effects of the emitted dust into the atmosphere results in: hazardous living conditions, respiratory diseases, short equipment life, smothering and poisoning vegetation, pollution of water resources, a general deterioration of the environment.

- Gas—The causes of gas emission into the atmosphere include: combustion of fossil fuels and other combustible wastes, slaking of spoils and oxidation of puritic and carbon wastes, and smelting of ores. The resulting emissions include the oxides of carbon, nitrogen, and sulfur, hydrogen sulfide, fluorides, chlorine, and ammonia. Some of these gases react photochemically to produce smog, sulfuric acid, nitric acid mists which create haze, paint and metal corrosion, hazardous living conditions, respiratory diseases. Generally these gases degrade the environment.

8. DATA RECORD DESCRIPTIONS

During the course of this study, as hazardous materials were identified, various related data were collected and have been placed on punched cards for automatic data processing. Three card types were developed and these are described below.

(1) Card Type 1

These are the basic cards, and provide the following information:

- Field 1 - Material name (alphabetical listing)
- Field 2 - Identification number (chronologically, according to alphabetical listing of material names)
- Field 3 - Quantity of annual material production (coded, see Table III-12 for code description)
- Field 4 - Waste disposal procedure for small and packaged lots (by MCA procedure number)
- Field 5 - Threshold limit values (toxicity) as recommended by the American Conference of Government Hygienists. Values are given in parts of vapor or gas per million parts of air by volume
- Field 6 - Specific gravity (gm. /ml. or density relative to water)
- Field 7 - Vapor density
- Field 8 - Flash point, °C
- Field 9 - Ignition temperature, °C
- Field 10 - Boiling point, °C
- Field 11 - Melting point, °C
- Field 12 - Solubility in water (Table III-13 indicates solubility code used).

Table III- 12
Hazardous Material Production Quantity Codes

Code	Production Quantity
0	Less than 0.5 million lb./yr.
1	0.5 - 1.0 million lb./yr.
2	1.0 - 10 million lb./yr.
3	10 - 50 million lb./yr.
4	50 - 100 million lb./yr.
5	100 - 500 million lb./yr.
6	500 - 1,000 million lb./yr.
7	1,000 - 2,000 million lb./yr.
8	2,000 - 5,000 million lb./yr.
9	Greater than 5,000 million lb./yr.

Table III-13
Codes for Hazardous Material Solubility in Water

Code	Description
NS	Not soluble
SL	Slightly soluble (5 gm./100 gm. water)
MS	Medium solubility (5-50 gm./100 gm. water)
VS	Very soluble (50-100 gm./100 gm. water)
IN	Infinite solubility (soluble in all proportions)

(2) Card Type 2

These cards contain the hazardous effects rating values and the principal industrial producers (SIC codes). Table III-14 describes these data records.

(3) Card Type 3

These cards include industry geographic locations, SIC codes (of industries for which waste factors were developed), value added in production data, the number of establishments, and the numbers of employees. Table III-15 describes these cards.

* * * * * *

Figures III-2, III-3, and III-4 illustrate the field layouts on each of the three data card types.

Table III-14
Material Hazard Rating and Industrial Source

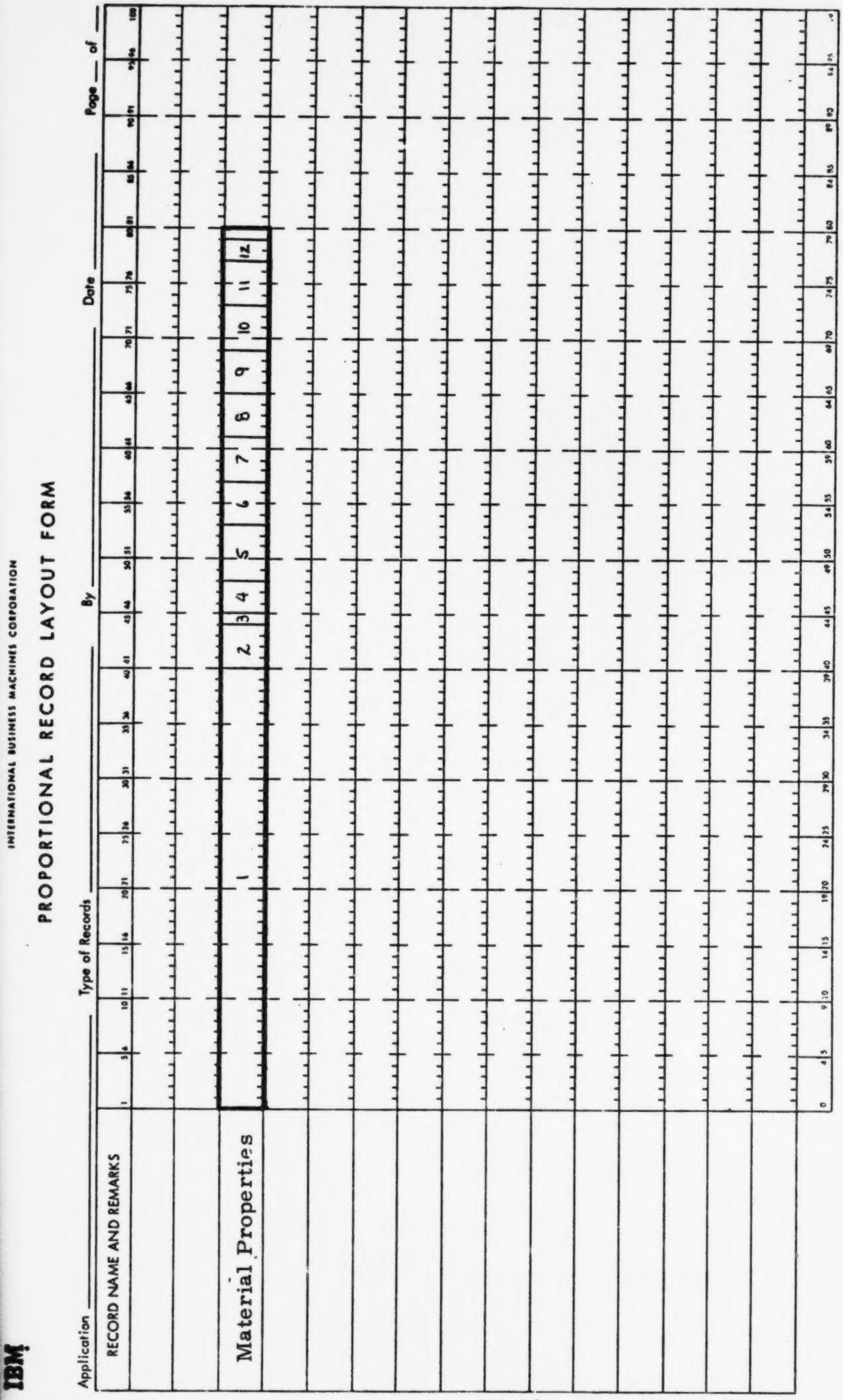
Location	Description
Field 1	Substance Identification Number
	Air Disposal
Field 2	Human Effects
Field 3	Explosion Reaction
Field 4	Ecological Effects
	Water Disposal
Field 5	Human Effects
Field 6	Explosion Reaction
Field 7	Ecological Effects
	Land Disposal
Field 8	Human Effects
Field 9	Explosion Reaction
Field 10	Ecological Effects
Field 11	Total Known Effect Rating
Field 12	Number of Unknowns
Field 13	Maximum Potential Effects Rating
Field 14	Production Rating
Field 15	Distribution Rating
Field 16	Total Production Distribution Rating
Field 17	Final Known Hazards Rating
Field 18	Maximum Potential Hazards Rating

Table III-14
(Continued)

Location	Description
Field 19	Metal Mining Industry
Field 20	Ordnance and Accessories Industry
Field 21	Food and Kindred Products Industry
Field 22	Textile Mill Products Industry
Field 23	Lumber and Wood Products Except Furniture
Field 24	Paper and Allied Products Industry
Field 25	Printing Publishing and Allied Industries
Field 26	Chemical and Allied Product Industry
Field 27	Petroleum Refining and Related Industries
Field 28	Rubber and Miscellaneous Plastics Products
Field 29	Leather and Leather Products Industry
Field 30	Stone, Clay, Glass, and Concrete Products
Field 31	Primary Metal Industries
Field 32	Fabricated Metal Products Except Ordnance, Machinery and Transportation Equipment
Field 33	Machinery Except Electrical
Field 34	Electrical Machinery Equipment and Supplies
Field 35	Professional Scientific and Controlling Instruments Photographic and Optical Goods, Watches, and Clocks
Field 36	Miscellaneous Manufacturing Industries

Table III-15
Industry Data

Location	Description
Field 1	Geographic Location
Field 2	SIC Code
Field 3	Value Added (millions)
Field 4	Number of Establishments
Field 5	Number of Employees (100)
Field 6	Geographic Location
Field 7	SIC Code
Field 8	Value Added (millions)
Field 9	Number of Establishments
Field 10	Number of Employees (100)
Field 11	Geographic Location
Field 12	SIC Code
Field 13	Value Added (millions)
Field 14	Number of Establishments
Field 15	Number of Employees
Field 16	Geographic Location
Field 17	SIC Code
Field 18	Value Added (millions)
Field 19	Number of Establishments
Field 20	Number of Employees



IBM

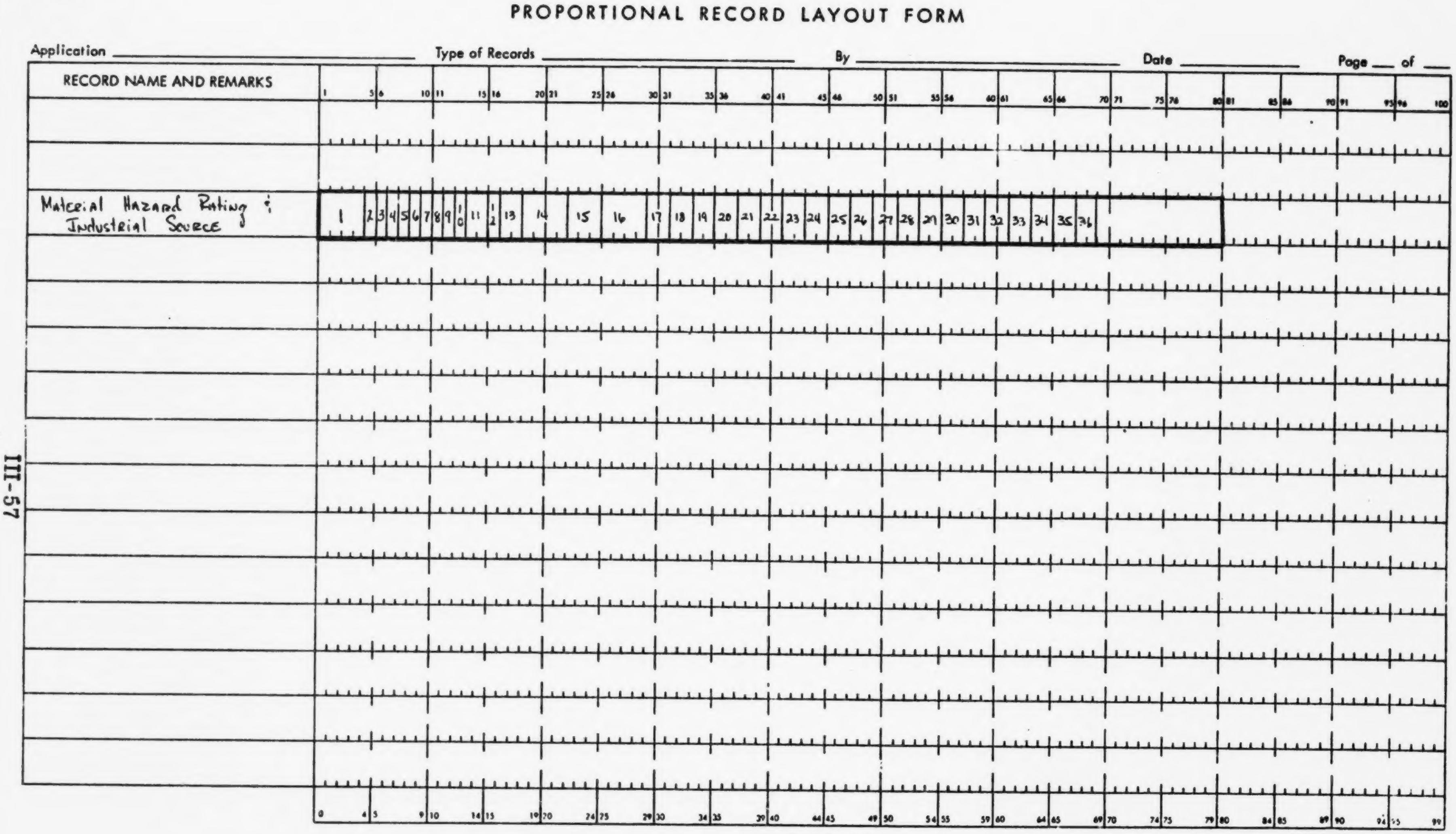
INTERNATIONAL BUSINESS MACHINES CORPORATION

PROPORTIONAL RECORD LAYOUT FORM

Application ______ Type of Records ______ By ______ Date ______ Page __ of __

RECORD NAME AND REMARKS												
Material Properties	1	2	3	4	5	6	7	8	9	10	11	12

FIGURE III-2
Layout Card
Type 1



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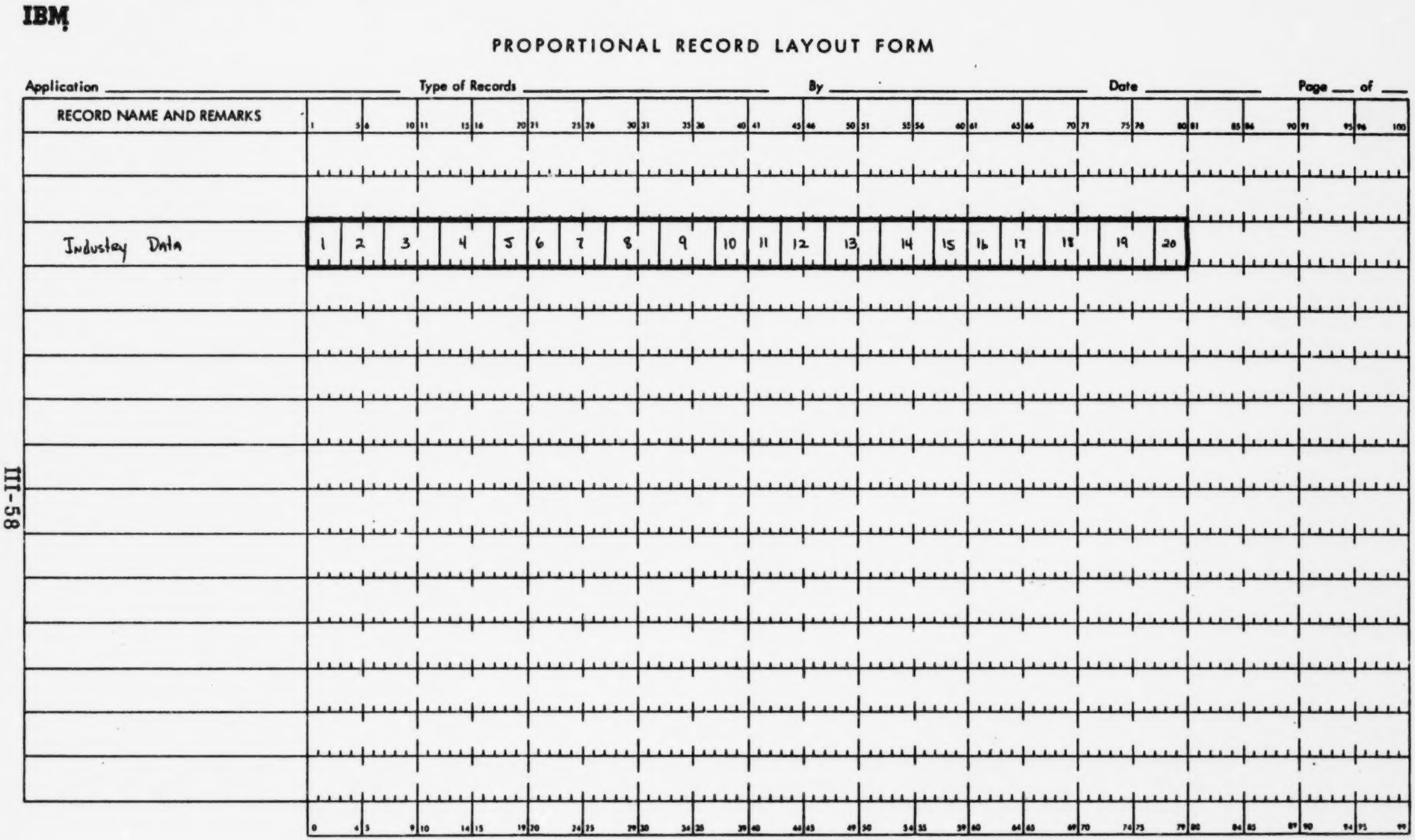
PROPORTIONAL RECORD LAYOUT FORM

Application ______ Type of Records ______ By ______ Date ______ Page __ of __

RECORD NAME AND REMARKS	
Material Hazard Rating & Industrial Source	1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36

1
5 6
10 11
15 16
20 21
25 26
30 31
35 36
40 41
45 46
50 51
55 56
60 61
65 66
70 71
75 76
80 81
85 86
90 91
95 96
100
0
4 5
9 10
14 15
19 20
24 25
29 30
34 35
39 40
44 45
49 50
54 55
59 60
64 65
69 70
74 75
79 80
84 85
89 90
94 95
99

FIGURE III-3
Layout Card
Type 2



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PROPORTIONAL RECORD LAYOUT FORM

Application ______ Type of Records ______ By ______ Date ______ Page ___ of ___

RECORD NAME AND REMARKS																				
Industry Data	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

FIGURE III-4
Layout Card
Type 3

(4) Use of the Data Records

As in any punched card system, a variety of sorts can be made depending upon the specific subject matter of interest. From card to card, the common thread of reference is the identification number assigned to the hazardous materials. Of particular interest in making sorts is the ability to focus on the rating of hazardous effects (i. e., depending upon whether the subject of interest is hazards to humans, fire and explosion hazards, ecological hazards, or overall hazard ratings). Additionally, as future research generates new or improved data, it can be entered into these data records with minimum difficulty.

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IV. SURVEY OF HAZARDOUS EFFECTS AND RATING OF HAZARDOUS MATERIALS

1. INTRODUCTION

Hazardous substances can produce measurable adverse effects in a number of environmental areas. Available literature reveals the wide scope of effects that have resulted from accidents, as well as from planned experiments involving laboratory animal and plant exposures to wide ranges of concentration levels and exposure time periods (see the list of references at the end of this chapter). Industrial health records and studies show a wide range of observed health effects due to both acute and chronic exposures of workers to various industrial materials (e.g., References 1, 2, 3). While the human health effects from industrial workplace exposures may be quite well documented, in many instances from medical records, often the contributing levels of exposure are not documented to provide good cause and effect relationships.

A material or substance is termed toxic if it can produce damage to a living organism. Its toxicity is a measure of the amount of damage that is caused by a specified amount of the substance.

Hazards, on the other hand, are usually thought of in terms of the probabilities of being involved in a situation which can cause damage. Frequently, the terms "toxic" and "hazardous" have been synonymous. This is true to some extent in this study and report, where a list of "hazardous materials" has been developed. Perhaps some justification can be offered in that one criterion used in developing the list was a measure of the production amounts of each substance, and the potential damages included those due to flame and explosion as well as toxic effects. Thus, the list includes substances which are hazardous because relatively large production amounts increase the probability of their causing widespread damage, and they are potentially damaging in more than one way.

The above connotation is continued in this section with the development of a rating system and rating of the list of hazardous materials. The indicated approach for the rating of hazardous materials can be concisely outlined as follows:

- Identify a representative list of hazardous substances
- Establish criteria for evaluating quantitatively all adverse effects that may result from exposures to the hazardous substances
- Establish criteria for evaluating the extent of the hazards involved, i. e., the extent in terms of geography and frequency of occurrence
- Develop algorithm for combining the individual ratings determined on the basis of criteria to arrive at a total rating for each substance
- Rank substances on basis of ratings.

2. ANALYTICAL PROBLEMS IN HAZARDOUS EFFECTS

Although the above logic for rating of the list of hazardous substances appears relatively simple, there are a great many complications which exist and which operate to limit severely the depth of an analysis that can be applied to development of the ratings. Most of these complications relate to the availability and quality of data needed for each substance to arrive at a defensible rating. Some of these complications are discussed below.

(1) Human Effects Data Limitations

Data on human effects resulting from severe exposures to hazardous or toxic substances are obtained principally from reconstruction of accident situations. A second major source of human effects information is extrapolation from experimental animal data. Both methods are fraught with uncertainties.

Accident data is sparse in terms of the detail and amounts needed for a list of nearly 500 substances (see Chapter II). Where accidents have occurred, the recording of information into the facts surrounding the accident has frequently been so unsystematic that the possibility of missing at least one key contributing factor is always present (Reference 4). This makes quantification of causes and effects uncertain, and accidents involving exactly the same set of circumstances do not usually occur with enough frequency to calibrate the measurement or reconstruction errors involved. Furthermore, some facts surrounding accidents are considered proprietary and, even though originally recorded, may not be generally available.

Extrapolations from animal data do not generally suffer from lack of data. More often, the problem evolves from several sets of data, one or more of which is anomalous and thereby casts uncertainty on human extrapolations. In addition, animals respond differently to doses of toxic substances administered by different dose injection routes. Thus, the results are dependent upon whether a dose was administered orally, intraperitoneally, intramuscularly, cutaneously, or via the respiratory route. This represents no unusual difficulty for an experiment designed specifically for use in extrapolating a result to humans. However, if attempt is made to infer human effects from odd bits of animal data which have been reported in many places, the question of dose route frequently arises and cannot be answered.

(2) Ecological Impact

Much of the ecological data for plants or animals suffers, to some extent, from the same limitations as described previously for human effects data. That is, very little plant or animal data have been taken in plant or animal natural habitat as a result of accidents, and when attempted, all causes and effects are not recorded. Likewise, extrapolations from one species of plant or animal to another are uncertain because of frequent anomalies observed in the available recorded data.

Furthermore, the full impact of hazardous substances on ecological systems may not be observable in isolated data on toxic effects to specific species. Important indirect or secondary impact may occur to co-inhabitants of a habitat as a result of exposures to hazardous materials in a natural environment, as opposed to an experimental laboratory. These impacts may involve predator and prey relationships, and the entire process of natural selection. The long-term result could be new and undesirable environmental balances.

(3) Time Factors

Adverse effects may occur to all ecological populations (which include humans) as a result of repeated exposures to sublethal acute dosage of toxic materials, or of continuous exposures to low-level concentrations of hazardous substances. Such exposures have produced carcinogenesis and mutagenesis in animals after extended periods of time (Reference 5). Similar results have not been observed in humans in equivalent times. Thus, another uncertain measure is added to the problem of animal extrapolations to humans, and the difficulty of obtaining definitive long-term cause-and-effect relationships for humans in industrial or urban environments is obvious.

Measures of persistence of hazardous substances become an important adjunct to time factors. The combination of low-level exposures and persistent agents can lead to major hazards in the form of lethal or damaging accumulations of a substance. Asbestos and mercury are perhaps the two most commonly known persistent hazards. Asbestos accumulates in humans and can lead to lung cancer after many years of low-level exposure (References 5, 6). Mercury is known to accumulate in aquatic species and may lead to serious effects in humans through a build-up of concentrations in the food chain (Reference 7). There are many other compounds which persist in nature and/or accumulate in food chains. Some of these are known or suspected; others have been observed occasionally but have not been quantified (References 1, 3).

3. DEVELOPMENT OF THE RATING SYSTEM

The rating of hazardous substances must reflect both the intensity or level of hazard and the extent of the hazard. Intensity or level of hazard can be provided in terms of potential effects. Extent of hazard involves production quantity and geographical distribution of a substance, and perhaps the number of ways that a substance can cause adverse effects on the populations that may be placed in jeopardy by its presence.

The rating of various hazardous substances can be accomplished in a number of ways and by the use of any number of criteria. From a practical point of view and in consideration of the state of knowledge concerning hazardous substances and related effects, it is better to limit the evaluation criteria to those for which appropriate evaluation data are available.

The approach taken during this study was to select criteria for evaluation of hazardous substances in such a way that the most important environmental effects were included for consideration. In this way, enough criteria were defined to provide for an adequate range of values for the rating of substances; at the same time, the criteria did not extend into areas in which little or no firm data could be found.

(1) Development of Effects Criteria

Waste materials can be disposed of or otherwise released (intentionally or unintentionally) through the following media:

- Air—by incineration, evaporation, or direct release of effluent as particulate matter, gases, or mists to the atmosphere
- Water—by chemical and biological treatment (in waste streams or holding ponds) or direct release of effluent to surface streams, ponds, lakes, estuaries; or by transport and deposit in ocean depths
- Soil—by direct deposit of sludge, ash, or other solid or semisolid waste forms in open pits, cover landfills or deep well injection.

Toxic substances may occur in solid, liquid, or gaseous state in any of the above media. However, a principal route of entry to receptors is commonly associated with each of the above media. In air, the main route of entry is via the respiratory system of humans, animals and plants. In water, the principal route of entry is by ingestion for humans and most animals, but for fish and aquatic plants the route is through the respiratory systems. In soil, the route is by direct contact for humans, animals and plants. There are, of course, other routes of entry. For example, toxic substances may enter humans by direct contact of air or water concentrations on skin areas, and soil organisms or land plants may ingest toxic materials by uptake of soil water or by inhalation of air contained in soil openings.

Human health and welfare, as well as animals and vegetation, may be exposed to hazardous situations involving flame and/or explosion caused by some substances. Other adverse effects may occur as a result of rapid or violent chemical reactions of substances. Flame, explosion, or reactions produce heat which may cause many compounds to emit highly toxic fumes or to react more vigorously with oxidizing materials. Some compounds can react rapidly with water or steam to produce toxic or flammable vapors. Acids may be produced by reactions, and heat generated by flame or reaction may, itself, be a serious hazard to many ecopopulations. Thus some substances may be more hazardous than others because they have a potential to cause damage by both toxic effects and by effects from flame, explosion, or reaction. But there are levels of toxicity and degrees of flammability, explosion and reaction, and this provides the basis for the development of useful criteria for evaluation and rating of potentially hazardous substances.

For this study, the measurable effects caused by hazardous substances were conveniently grouped into two principal categories:

- Effects on human health and welfare
- Effects on other ecological populations.

The human health and welfare category includes effects resulting from flame, explosion, or reaction as well as exposure. to toxic substances. The category involving other ecological populations includes both plants and animals as appropriate in land, water, or air habitats. Both categories include exposures to toxic materials in the form of solids, liquids, or gases but in a selective way, as described later, rather than all-inclusively.

The matrix of effects considered for rating the list of hazardous substances took the form shown in Table IV-1. Each row and column combination of the matrix required a set of criteria for use in determining ratings. In light of the human and ecological effects data limitations described earlier, no attempt was made to develop a sophisticated rating scale involving a large number of possible values which would have required highly-precise

Table IV-1
Matrix of Factors for Rating the Level of Effects for the List of Hazardous Substances

Medium For Disposal	Hazard in Terms of Potential Effects		
	Human Populations		Eco Populations
	Toxic Effects (T_H)	Flame/Explosion/ Reaction (F_H)	Toxic Effects (T_F)
Air (A)	AT_H	AF_H	AT_E
Water (W)	WT_H	WF_H	WT_E
Soil (S)	ST_H	SF_H	ST_E

estimates of effects in order to rate them properly. Instead, a very simple three-valued scale was developed for each element of the matrix. For each element, the ratings were:

3—Severely hazardous

2—Slight to moderate hazard

1—Minimal hazard

U—Effects unknown.

It is recognized that the scale of 1-3 is a narrow band likely to produce ratings that tend to group many materials into clusters in the overall rating scale, and that a wider spread in the relative ratings would be desirable. However, the limitations noted earlier with respect to knowledge of human and ecological effects of materials are such that the rating precision needed for use of a wider scale (e. g., 1-10) or the precision that would be implied if a wider scale were imposed, are not justified by the data available.

For each element of the matrix, an appropriate descriptive statement of each rating criterion was developed. Effects data, available in a number of sources, are not always given in the same units. Sometimes, even though the units are the same, the exposure times are different, which leads to a different implication.

To improve the consistency of the ratings, sets of guidance values were developed for each criterion. That is, specific numerical values were developed for each criterion. That is, specific numerical values in terms of concentrations or doses for both acute and chronic exposure modes were included wherever the available background data were adequate for such development.

It was concluded arbitrarily that where effects were unknown, or at least were not available in the material gathered for this study, a "U" would be inserted in lieu of an estimated or inferred value. The use of the effects rating values in reaching a final hazard rating and the implications of inserting "U" for unknowns are discussed in a later section. All details and definitions concerning the criteria for rating the elements of the matrix of effects are included in Tables IV-3 through IV-13 at the end of this section of the report.

(2) Development of Extent of Hazard Criteria

Direct quantitative measures of the extent of hazards are difficult to obtain. Ideally, such measures should include the specific amounts of each potentially hazardous material reaching waste status and a measure of their geographical distribution. Hazardous wastes occur in a number of ways as described in the surveys of industrial sections which were included earlier in this report. Because waste materials occur mostly as complex mixtures in industrial waste streams which are frequently changing in composition, currently available waste inventories have not included the detail necessary to provide the desired quantification of specific compounds.

The extent of hazard should also include a measure of the period of time over which substances may be hazardous. However, accurate measures of the persistence of most hazardous substances are not generally available, except for rough estimates for a few pesticide compounds (see References 8, 9).

For this study, a search was undertaken to obtain available production information which could serve as a reliable indicator of the extent of hazardous substances. A survey of the list of compounds was conducted to obtain production amounts, major manufacturers, usual shipping mode and major used for each substance.

Following a rationale that the extent of a hazardous substance is reflected in a combination of its production amounts and subsequent distribution, the ratings in Table IV-2 were selected for use in rating the list of substances.

Table IV-2
Matrix of Factors for Rating the Extent of Hazard for the List of Hazardous Substances

Production Criteria (lbs/year)	Rating Value	Distribution Criteria	Rating Value
$>10^8$	1.5	Wide Distribution to Many Consumers	.5
$\leq 10^8$ But $\geq 10^7$	1.25	Used in Bulk by Limited Number of Consumers	.25
$<10^7$	1.0	Largely Consumed in Same Plant	.00

The amount produced and distribution pattern indicated the extent of potential exposure to the toxic effects of materials. This exposure risk was assumed to be roughly proportional to the production amounts and scope of distribution and, therefore, it was planned that the rating values be used as multiplicative (weighting) factors to be applied to the total effects rating as developed in the succeeding section. In arriving at the rating values of Table IV-2, the following rationales were employed:

- The actual toxicity should dominate the relative ratings, but the exposure possibilities should distinguish between compounds of equivalent toxicity.

- Production amounts and distribution should not impact negatively to reduce total effects ratings; therefore, the smallest factor should be a one (i. e., 1.0).
- There should be a measure of equivalence between small production levels with wide distribution and large production levels with limited distribution.
- The total multiplier should be no more than two (to avoid undue bias) and be a measure of the amount produced and its source of distribution.

The criteria used to establish the ratings shown in Table IV-2 are contained in Tables IV-14 and IV-15 (presented at the end of this chapter).

4. METHOD OF RATING AND RESULTS

The methods described in the preceding two sections for rating the level of effects and the extent of hazard were combined to provide the complete methodology for rating each substance of the hazardous substance list. Using the criteria of Tables IV-5 through IV-13 (presented at the end of this chapter) and effects information available in a number of sources, coded effects ratings were developed for each element of the effects rating matrix of Table IV-1 for each substance.

In reaching a coded rating value, no single reference provided the rating, although heavy reliance was placed on Dangerous Properties of Industrial Materials (Reference 1). The basic procedure used to obtain final hazard ratings was to obtain initial estimates of effects ratings from Reference 1 and then compare these estimates with other available sources which included, but was not limited to, References 1, 2, 3, and 10 through 19. If the other sources confirmed the estimate taken from Reference 1, the rating was accepted; but if other sources differed, an average of all available information became the basis for the rating. No attempt was made to rate each substance for both acute and chronic exposures because of paucity of data, particularly on chronic exposures. Data corresponding to either acute or chronic exposure was used to produce a rating. If both were available, the one producing the larger hazard rating was used.

A final weighted total effects rating (TER) was computed using the following expression:

$$TER = (AT_H)W_1 + (AF_H)W_2 + (AT_E)W_3 + (WT_H)W_4 + (WF_H)W_5 + (WT_E)W_6 + (ST_H)W_7 + (SF_H)W_8 + (ST_E)W_9$$

where the parenthetical terms refer to the appropriate row and column entries of the matrix in Table IV-1, and W_i refers to a specific weight for each matrix entry. In developing the ratings for this study, no really good justification could be found for adjusting the weights from term to term (of the above equation) and a weight of one was, therefore, assumed at all times. It is suggested that the use of weighting values, in developing the TER, be applied to reflect priorities. Priorities can be established that are indicative of the interest of the user, (e.g., whether hazards to humans are given greater significance than hazards to other species, and weighting values should then be assigned accordingly. Thus, in future work (particularly as priorities are defined) it may be desirable to introduce specific term weights and recalculate ratings. This will, of course, be a routine adjustment once a punched card deck or tape is prepared for the basic effects data.

The second step to a final hazard rating involved the use of production/distribution data, and the criteria of Tables IV-14 and IV-15 to obtain a hazard extent rating (HER) from Table IV-2. The hazard rating for each substance is then the product of the total effects rating (TER) (previously discussed), and the hazard extent rating (HER):

Hazard rating (HR) = (TER) x (HER)

In computing the hazard ratings, there were many substances for which data were not complete and rating values could not be provided for all components of the system. At these points, a decision was made to insert the letter "U" to signify unknown or unavailable information. The number of unknown pieces of data was totaled and recorded, and based on the assumption that it would be desirable to produce conservative hazard ratings, the concept of "potential hazard ratings" was introduced, through which specific values can be assigned to the "unknowns." This concept results in two additional rating scores for the materials listed. The first of these is termed the maximum potential effects rating (MPER), which is computed by assigning a value of three (maximum hazard value) to each unknown, summing those and adding the result to the total effect rating:

MPER = 3U + TER

The second "potential" rating is termed the maximum potential hazard rating (MPHR), which is computed by multiplying the maximum potential effects rating by the hazard extent rating:

MPHR = MPER x HER,

to produce the highest overall hazard rating.

Thus, the rating system developed actually includes five ratings (TER, HER, MPER, HR and MPHR), and is a flexible system that can accommodate data that may be developed in the future. The system is also readily amenable to altered weighting factors and the incorporation of a wider spread in the scale of individual values that may be justified by future research.

A simple worksheet was prepared for computing the hazard rating of each substance. A sample copy is included in Table IV-16 and a completed sample is given in Table IV-17. The hazard ratings for each substance were computed and the results are included in Table IV-18. While Table IV-18 gives ratings for the hazardous materials listed in Chapter II (Table II-6, page II-29), Table IV-19 provides examples of additional potentially hazardous materials, with rating scores. (These four tables are presented at the end of this chapter.) This latter group typifies materials for which a great number of unknowns exist with respect to the hazards they might present. They have been included here to illustrate that various cutoff points need to be established and observed in order to differentiate among the meanings of ratings for potentially hazardous compounds. Such compounds show known effects ratings that are low, but high potential effects ratings. In the total hazard rating columns of the latter two tables, two final rating columns are given. The first provides a rating based on known data, while the second provides a potential rating based on the known ratings plus maximum possible component ratings for each unknown. Used together, the two columns provide a range of values within which the actual rating will fall when all data become known.

Table IV-20 lists certain hazardous materials used as warfare agents, with hazard ratings where possible. Further, three additional lists of hazardous wastes resulting from Department of Defense activities are presented in Tables IV-21, IV-22 and IV-23. These three lists include explosive materials and compounds; typical air and water pollutants involved in conventional munitions production, and a list of typical hazardous waste compounds subcategorized by maintenance, supply and weapons systems support operations. Some of these compounds are included on the list of hazardous materials developed in this study because they have other industrial or commercial uses. Where a rating has been developed, it is included in parentheses following the compound. Where two numbers are given, the second refers to the partial rating appropriate to the main list, e.g., air exposure or water exposure only.

Table IV-3
Rules Used During Rating of Hazardous Substances

1. Chronic exposures are arbitrarily assumed to be 1/20 to 1/100 of acute exposures.
2. If effects measurements could not be found in the available data and effects could not be clearly established based on descriptive statements of effects, the letter, U, signifying unknown or unavailable was inserted in place of a rating value.
3. The simple sum of component effects provides a total effects rating, and no justification could be provided for implementing separate weightings on each component rating.
4. If production amounts could not be determined from available sources, it was assumed that the production amount was low and an arbitrary value of 1.0 was assigned.
5. The simple sum of production rating and distribution rating provides an extent of hazard rating, and no justification could be provided for implementing separate weightings on each component rating.
6. The product of the effects rating and the extent of hazard rating gives the final hazard rating.

Table IV-4
Definitions of Terms Used in Criteria

LC_{50}	Lethal concentration fifty: concentration which administered by the respiratory route would be lethal to fifty percent of the exposed population.
LD_{50}	Lethal dose fifty: dose in terms of milligrams per kilogram of body weight which if ingested by the oral route would cause death to fifty percent of the exposed population.
TLV	Threshold limit value: the concentration (mg/m^3) or dose (mg/kg body weight) to which receptors (humans, animals, or plants) may be exposed repeatedly or continuously day after day without suffering adverse effects.
Toxic Substance	An element, compound, or material which can produce damage to a living organism.
Acute Exposure	Short time (less than one hour) exposures to relatively large concentrations or doses of toxic substances. Acute doses are generally ingested as a single dose.
Chronic Exposure	Long-term (order of days to years) exposures to relatively small concentration or doses of toxic substances. Chronic doses are generally small doses repeated over periods of days to years.
Guidance Values	Values of concentrations, dose, etc., provided as guidelines for use in rating hazardous substances. Any one of the several provided can serve as the basis for a rating (i.e., not intended that all criteria be met for a rating).

Table IV-5
Human Effects Rating Criteria: Toxic Effects in Air

3 Severely hazardous. Very highly toxic causing death or residual injuries to persons exposed to relatively low concentrations. Has potential to be carcinogenic. Guidance values:

LC_{50}^{*} -	$\leq$ 5000 mg/m^3	(acute * exposure)
LC_{50} -	$\leq$ 250 mg/m^3	(chronic * exposure)
TLV* -	$\leq$ 500 mg/m^3	(acute exposure)
TLV -	$\leq$ 25 mg/m^3	(chronic exposure)

2 Slight to moderate hazard. Short intense exposures or continued exposures at lower concentration levels may cause serious temporary or minor residual injury. Guidance Values:

LC_{50} -	5000 to 50000 mg/m^3	(acute)
LC_{50} -	250 to 2500 mg/m^3	(chronic)
TLV -	500 to 5000 mg/m^3	(acute)
TLV -	25 to 250 mg/m^3	(chronic)

1 Minimal Hazard. Lethal at concentrations which are not likely to occur at all, or at most over very limited areas. Effects generally confined to minor symptoms and injuries of temporary nature. Guidance values:

LC_{50} -	>50000 mg/m^3	(acute)
LC_{50} -	>2500 mg/m^3	(chronic)
TLV -	>5000 mg/m^3	(acute)
TLV -	>250 mg/m^3	(chronic)

U Unknown

* See Table IV-4 for list of definitions.

Table IV-6
Human Effects Rating Criteria: Toxic Effects in Water*

3 Severely hazardous. Very highly toxic causing lethalities or severe residual injuries to persons acquiring relatively small doses. Has potential to be carcinogenic. Guidance values:

LC_{50} -	$\leqq$ 3500 mg/liter of water	(acute ingestion)
LC_{50} -	$\leqq$ 35 mg/liter of water	(chronic ingestion)
TLV -	$\leqq$ 350 mg/liter of water	(acute ingestion)
TLV -	$\leqq$ 3.5 mg/liter of water	(chronic ingestion)

2 Slight to moderate hazard. Lethal only at moderate concentrations. In general causes serious temporary injury or minor residual damages. Guidance values:

LC_{50} -	3500 to 35000 mg/liter of water	(acute)
LC_{50} -	35 to 350 mg/liter of water	(chronic)
TLV -	350 to 3500 mg/liter of water	(acute)
TLV -	3.5 to 35 mg/liter of water	(chronic)

1 Minimal hazard. Effects generally confined to minor symptoms and injury of a temporary nature. Guidance values:

LC_{50} -	$>$ 35000 mg/liter of water	(acute)
LC_{50} -	$>$ 350 mg/liter of water	(chronic)
TLV -	$>$ 3500 mg/liter of water	(acute)
TLV -	$>$ 35 mg/liter of water	(chronic)

U Unknown

* Values based on milligrams of toxic substance per liter of water (i.e., water concentration). Lethal concentration assumes ingestion of one liter of water containing one lethal dose (LD_{50}) of substance by 70 kilograms man for an acute exposure.

Table IV-7

Human Effects Rating Criteria: Toxic Effects in Soil

3	Severely hazardous percutaneously on direct contact. May release lethal secondary compounds in the form of vapors or mists to the atmosphere, or in liquid or particulate form to surface or ground waters. May be only moderately toxic (as described under 2 below) but is highly persistent. In contact with skin, causes second- and third-degree burns and is very injurious to the eyes on short direct contact. Extended periods of contact could cause death. Has potential to be carcinogenic.
2	Moderately severe skin irritant. Causes severe smarting of skin and first-degree burns on short direct contact exposure. Causes severe pain and second degree burns after prolonged contact.
1	Minimal hazard. No hazard for short time contact exposure. Mild irritation and smarting of skin in contact for prolonged period.
U	Unknown.

Table IV-8

Human Hazards Rating Criteria: Flame, Explosion, and Reaction in Air

3	Severe hazard. Vaporizes quickly at atmospheric pressures and normal ambient temperatures. Readily dispersible and burnable in air. High liklihood of spontaneous combustion and/or explosive reaction. Exposure to flame or violent reaction may produce lethal gases, vapor, fumes, or mist. Liquid and vapor flash points below 100°F.
2	Moderate hazard. Generally must be heated or exposed to unusually high ambient temperatures to ignite. Under certain limited conditions can ignite spontaneously and burn rapidly but no explosion or violent reactions. Exposure to flame or violent reaction vapors, gases, fumes, etc. which may be toxic, but not lethal. Includes liquids and vapors with flash point over 100°F, and solids emitting highly flammable vapors.
1	Minimal hazard. Must be preheated to ignite. Includes liquids, solids, semi-solids with very high flash points. No generation of toxic mists, fumes, etc. occurs.
U	Unknown.

Table IV-9

Human Hazards Rating Criteria: Flame, Explosion, and Reaction in Water

3	Severe hazard. Will react explosively with water without requiring heat or confinement. Violent reactions may produce lethal or highly toxic vapors and/or acids that may cause serious and permanent injury.
2	Moderate hazard. May react violently with water, but only under certain very limited circumstances. May form potentially explosive mixtures with water, but requires catalyst to ignite. Reactions may release harmful, but not lethal or residual injuries. In general, effects are temporary with no residual damages.
1	Minimal hazard. Limited or no reaction in water. Any release of energy is non-violent. No generation of toxic vapors occurs.
U	Unknown

Table IV-10

Human Hazards Rating Criteria: Flame, Explosion, and Reaction in Soil

3	Severe Hazard. Readily capable of detonation and explosive decomposition or reaction at normal ambient temperatures and pressures. Will detonate as result of mechanical shock or local thermal shock. Reacts readily with own oxides or with other oxidizing materials. Can ignite spontaneously and/or react violently if exposed to moisture in soil. Ignition or reaction can produce lethal vapors, fumes, etc.
2	Moderate hazard. Can readily undergo violent chemical change with rapid release of energy, but will not detonate explosively or react violently except under very special circumstances such as heating under confinement. Can ignite and burn rapidly or react to produce harmful, though not lethal, vapors and fumes if exposed to modest increase of temperature or if moisture is encountered.
1	Minimal hazard. General stable substances. Very limited potential for reaction or combustion. No toxic fumes or vapors associated with any reactions or combustion that may occur.
U	Unknown.

Table IV-11
Ecological Effects Rating Criteria: Toxic Effects in Air

3 Severe hazard. Highly toxic, causing death or residual damage to animals and/or plants exposed to atmospheres contaminated at relatively low concentration levels, or to animals accumulating small doses of the toxic substance. Guidance values:

LC_{50} -	$\leq 2000\ mg/m^{3*}$ or $\leq 100\ mg/kg^{**}$	(acute exposure)
LC_{50} -	$\leq 20\ mg/m^3$ or $\leq 1.0\ mg/kg$	(chronic exposure)
TLV -	$\leq 200\ mg/m^3$ or $\leq 10\ mg/kg$	(acute exposure)
TLV -	$\leq 2\ mg/m^3$ or $\leq 0.1\ mg/kg$	(chronic exposure)

2 Slight to moderate hazard. Causes temporary damage to most species and is lethal to only a few extra sensitive species at moderate concentrations. Guidance values:

LC_{50} -	2000 to 20000 mg/m^3 or 100 to 1000 mg/kg	(acute)
LC_{50} -	20 to 200 mg/m^3 or 0.1 to 10 mg/kg	(chronic)
TLV -	200 to 2000 mg/m^3 or 10 to 100 mg/kg	(acute)
TLV -	2 to 20 mg/m^3 or 0.1 to 1.0 mg/kg	(chronic)

1 Minimal hazard. Lethal only at concentrations which are not likely to occur at all, or at most over very limited areas. Causes only minor injury of temporary nature. Guidance values:

LC_{50} -	$> 20000\ mg/m^3$ or $> 1000\ mg/kg$	(acute)
LC_{50} -	$> 200\ mg/m^3$ or $> 10\ mg/kg$	(chronic)
TLV -	$> 2000\ mg/m^3$ or $> 100\ mg/kg$	(acute)
TLV -	$> 20\ mg/m^3$ or $> 1.0\ mg/keg$	(chronic)

U Unknown.

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*Concentration of toxic substance per cubic meter of air

**Loss of toxic substance (mg) per kilogram of animal body weight

Table IV-12
Ecological Effects Rating Criteria: Toxic Effects in Water

3 Severe hazard. Lethal to fish and/or other aquatic life in general in low concentrations. Guidance values:

LC_{50}	-	$\leq$100 mg/liter water	(acute exposure)
LC_{50}	-	$\leq$1 mg/liter water	(chronic exposure)
TLV	-	$\leq$10 mg/liter water	(acute exposure)
TLV	-	$\leq$0.1 mg/liter water	(chronic exposure)

2 Slight to moderate hazard. Lethal to only a few sensitive species of fish on other aquatic life at moderate concentrations. Guidance values:

LC_{50}	-	100 to 1000 mg/liter water	(acute)
LC_{50}	-	1 to 10 mg/liter water	(chronic)
TLV	-	10 to 100 mg/liter water	(acute)
TLV	-	0.1 to 1.0 mg/liter water	(chronic)

1 Minimal hazard. Requires very high concentrations for exposures that would cause lethalities. Not likely to occur over large volumes of water. Guidance Values:

LC_{50}	-	$>$ 1000 mg/liter water	(acute)
LC_{50}	-	$>$10 mg/liter water	(chronic)
TLV	-	$>$100 mg/liter water	(acute)
TLV	-	$>$1.0 mg/liter water	(chronic)

U Unknown.

Table IV-13
Ecological Effects Rating Criteria: Toxic Effects in Soil

3	Severe Hazard. Highly lethal on contact to most vegetation and/or earth organisms. May be soluble in water and can flow with surface or ground waters to affect vegetation and/or aquatic life in remote streams, ponds, lakes, etc. Potential hazard to public or private fresh water supplies because of persistence.
2	Moderate hazard. Lethal on contact to only sensitive species of plants and/or earth organisms. General damage to vegetation and earth organisms may be substantial but is reversible. May affect remote vegetation or aquatic life only under unusual circumstances of surface drainage or ground water penetration.
1	Minimal hazard. Minimal damage to plants and or organisms, all reversible. No potential for damage to remote aquatic life or vegetation. No threat to public or private fresh water supplies.
U	Unknown.

Table IV-14
Hazardous Substances Production (or Consumption)* Rating Criteria

1.5	Large production (or consumption); amounts exceeding 10^8 pounds (50,000 short tons) annually.
1.25	Moderate production (or consumption); amounts at least 10^7 pounds (5000 short tons) but less than 10^8 pounds annually.
1.0	Low production (or consumption); amounts less than 10^7 pounds annually.
U	Unknown

*Production or consumption amount, whichever was larger, was used to determine code rating.

Table IV-15
Hazardous Substances Distribution Rating Criteria

0.5	Wide distribution-based on more than 10 major producers; shipments in less than tank car containers for distribution to many consumers; and used as both intermediate industrial and consumer product.
0.25	Moderate distribution-based on 5 to 10 major producers; shipments mostly in bulk or tank cars to limited number of consumers; and used as either intermediate industrial product or consumer product, but not both.
0.0	Limited distribution - based on less than 5 major producers; used mostly or entirely by manufacturer.

Table IV-16
Sample Worksheet for Computing Substance Hazard Rating

Compound ____________________

		Initial Rating	Weight	Final Rating
Air Disposal	Human toxic effects	-	-	____
	Flame/Explosion	-	-	____
	Ecoeffects	-	-	____
Water Disposal	Human toxic effects	-	-	____
	Flame/Explosion	-	-	____
	Ecoeffects	-	-	____
Soil Disposal	Human toxic effects	-	-	____
	Flame/Explosion	-	-	____
	Ecoeffects	-	-	____
Total Effects Rating (Sum of above)				____
Number of Unknowns above				____
Maximum Potential Effects Rating	(unknowns x 3 + total effects rating)			____
Production Rating				____
Distribution Rating				____
Hazard Extent Rating (Sum of Production & Distribution)				____
Hazard Rating (Total Effects Rating x Hazard Extent Rating)				____
Maximum Potential Hazard Rating	(Maximum Potential Effects Rate & Extent of Hazard Rating)			____

Table IV-17
Sample Worksheet for Computing Substance Hazard Rating

Compound Cadmium Oxide

		Initial Rating	Weight	Final Rating
Air Disposal	Human toxic effects	3	1	3
	Flame/Explosion	2	1	2
	Ecoeffects	2	1	1
Water Disposal	Human toxic effects	3	1	1
	Flame/Explosion	1	1	1
	Ecoeffects	U	1	U
Soil Disposal	Human toxic effects	1	1	1
	Flame/Explosion	2	1	2
	Ecoeffects	U	1	U
Total Effects Rating (Sum of above)				14
Number of Unknowns above				2
Maximum Potential Effects Rating	(unknowns x 3 + total effects rating)			20
Production Rating				1.0
Distribution Rating				0.5
Hazard Extent Rating (Sum of Production & Distribution)				1.5
Hazard Rating (Total Effects Rating x Hazard Extent Rating)				21
Maximum Potential Hazard Rating	(Maximum Potential Effects Rate & Extent of Hazard Rating)			30

Table IV-18
Compounds Found Hazardous by Rating System

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Total Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Acetaldehyde	2	2	3	2	1	3	2	2	2	19		19	1.5	0	1.50	28	28
Acetic Acid	2	2	1	2	1	3	2	U	2	15	1	18	1.5	.25	1.75	26	31
Acetic Anhydride	2	2	2	3	3	2	3	2	U	19	1	22	1.5	.25	1.75	33	38
Acetone	2	2	2	2	1	1	1	2	U	13	1	16	1.5	.25	1.75	23	28
Acetone Cyanhydrin	3	2	2	3	3	3	2	2	U	20	1	23	1.5	.25	1.75	35	40
Acetonitrile (Methyl Cyanide)	2	2	2	2	2	2	1	2	U	15	1	18	1.5	.25	1.75	26	31
Acetyl Chloride	3	2	3	3	2	U	3	2	U	18	2	24	1.0	.50	1.50	27	36
Acetylene	1	2	1	1	1	2	1	2	U	11	1	14	1.5	.25	1.75	19	24
Acridine	2	2	1	2	1	3	2	1	U	14	1	17	1.0	.25	1.25	17	21
Acrolein	3	2	2	3	U	3	2	2	U	17	2	23	1.0	.25	1.25	21	29
Acrylic Acid	3	2	2	3	1	3	3	2	U	19	1	22	1.25	.50	1.75	33	38
Acrylonitrile	2	2	3	3	1	3	1	2	U	17	1	20	1.5	.25	1.75	30	35
Aldrin	3	2	2	3	U	3	2	2	U	17	2	23	1.0	.25	1.25	21	29
Allyl Alcohol	2	2	3	2	1	3	2	2	U	17	1	20	1.0	.25	1.25	21	25
Allyl Chloride	3	2	U	3	1	1	3	1	U	14	2	20	1.0	.25	1.25	17	25
Aluminum Fluoride	3	2	2	3	U	U	2	2	3	17	2	23	1.5	.50	2.0	34	46
Aluminum Oxide (Alumina)	2	2	1	1	1	U	1	1	3	12	1	15	1.0	.25	1.25	15	19
Aluminum Sulfate	3	2	3	3	2	2	3	2	U	20	1	23	1.5	.50	2.0	40	46
Ammonia (Aqua-Ammonium Hydroxide)	2	2	U	3	1	3	2	2	U	15	2	21	1.5	.25	1.75	26	37
Ammonium Chloride	1	2	2	1	1	2	1	1	U	11	1	14	1.25	.50	1.75	19	24
Ammonium Chromate	3	2	U	3	1	2	3	2	U	16	2	22	1.25	.50	1.75	28	38
Ammonium Dichromate	3	2	2	2	1	2	3	2	U	17	1	20	1.25	.25	1.50	25	30
Ammonium Fluoride	3	2	2	3	1	2	3	2	U	18	1	21	1.25	.50	1.75	31	37
Ammonium Nitrate	1	2	U	1	1	2	1	3	U	11	2	17	1.5	.25	2.0	22	34
Ammonium Perchlorate	2	3	U	2	1	U	2	3	U	13	3	22	1.5	.50	2.0	26	44
Ammonium Persulfate	1	2	1	1	1	3	1	2	U	12	1	15	1.25	.50	1.75	21	26
Ammonium Picrate (Dry)	3	3	1	3	1	U	3	3	U	17	2	23	1.25	.50	1.75	30	40

Table IV-18
(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Ammonium Picrate (Wet)	3	3	U	3	1	U	3	2	U	15	3	24	1.25	25	1.5	22	36
Ammonium Sulfide	2	3	3	3	2	3	2	3	U	21	1	24	1.5	.25	1.75	37	42
Amyl Acetate (Banana Oil)	2	2	2	2	1	3	1	2	U	15	1	18	1.0	.25	1.25	19	22
Amyl Alcohol (Fusel Oil)	2	2	3	3	1	2	2	2	U	17	1	20	1.25	.25	1.5	25	30
Aniline	3	2	1	3	1	2	3	2	U	17	1	20	1.5	25	1.75	30	35
Anthracenes	U	2	3	3	1	U	U	1	U	10	4	24	1.5	.25	1.75	18	42
Antimony	3	2	2	3	1	U	2	2	U	15	2	21	1.25	25	1.5	22	31
Antimony Pentachloride	3	2	2	3	1	U	2	2	U	15	2	21	1.0	25	1.25	19	26
Antimony Pentafluoride	3	2	2	3	1	U	2	2	U	15	2	21	1.0	.25	1.25	19	26
Antimony Pentasulfide	3	2	1	2	2	1	1	2	U	14	1	17	1.0	5	1.5	17	21
Antimony Potassium Tartrate	3	2	1	3	1	3	2	2	U	17	1	20	1.0	.25	1.25	21	25
Antimony Sulfate	3	2	1	3	1	U	2	2	U	14	2	20	1.0	.25	1.25	17	25
Antimony Sulfide	3	2	1	3	2	U	2	2	U	15	2	21	1.0	.5	1.5	22	31
Antimony Triethyl (Triethylstibine)	3	3	U	3	1	U	2	2	U	14	3	23	1.0	.25	1.25	17	29
Antimony Trichloride	3	2	U	3	2	3	3	2	U	18	2	24	1.0	.5	1.5	27	36
Antimony Trifluoride	3	2	U	3	1	2	2	2	U	15	2	21	1.0	.25	1.25	19	26
Antimony Trimethyl (Trimethylstibine)	3	3	U	3	1	U	2	2	U	14	3	23	1.0	.25	1.25	17	29
Antimony Trioxide	3	2	1	3	1	3	2	2	U	17	1	20	1.0	.25	1.25	21	25
Arsenic	3	2	3	3	1	3	2	2	3	22		22	1.25	.5	1.75	38	38
Arsenic Chloride	3	2	3	3	2	3	2	2	3	23		23	1.0	25	1.25	29	29
Arsenic Diethyl	3	3	3	3	2	3	2	3	3	25		25	1.0	.25	1.25	31	31
Arsenic Dimethyl	3	3	3	3	1	3	2	2	3	23		23	1.0	.25	1.25	29	29
Arsenic Pentaselenide	3	2	3	3	1	3	2	2	3	22		22	1.0	.25	1.25	27	27
Arsenic Trichloride	3	3	3	3	1	3	2	2	3	23		23	1.0	.25	1.25	29	29
Arsenic Trioxide	3	3	3	3	1	3	2	2	3	23		23	1.0	.25	1.25	29	29
Asbestos Particles	3	1	U	1	1	U	1	1	U	8	3	17	1.5	.25	1.75	14	30
Barium Carbonate	2	1	1	2	2	1	1	1	U	11	1	14	1.5	25	1.75	19	24

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(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Barium Chloride	2	1	2	3	2	3	1	1	U	15	1	18	1.0	.5	1.5	22	27
Barium Cyanide	3	2	U	3	2	U	2	2	U	14	3	23	1.0	.25	1.25	17	29
Barium Fluoride	3	2	2	3	1	1	3	2	U	17	1	20	1.0	.25	1.25	21	25
Barium Nitrate	2	2	U	2	1	1	1	2	U	12	2	18	1.0	.25	1.25	15	22
Barium Sulfide	2	3	U	2	2	U	1	3	U	13	3	22	1.0	.25	1.25	16	27
Benzene	2	2	1	2	1	3	2	2	U	15	1	18	1.5	.5	2	30	36
Benzene Hexachloride	2	2	3	3	1	3	2	2	1	19		19	1.25	.5	1.75	33	33
Benzene Sulfonic Acid	3	2	1	3	1	2	3	2	U	17	1	20	1.0	.25	1.25	21	25
Benzoic Acid	1	1	1	1	1	2	1	1	U	9	1	12	1.25	.25	1.5	13	18
Benzyl Chloride	3	2	U	3	2	3	3	2	U	18	2	24	1.25	.25	1.5	27	36
Beryllium Carbonate	3	2	3	1	1	U	3	1	U	14	2	20	1.0	.25	1.25	17	25
Beryllium Chloride	3	2	3	2	1	U	3	2	U	16	2	22	1.0	.25	1.25	20	27
Beryllium Hydroxide	3	2	3	2	1	U	3	1	U	15	2	21	1.0	.25	1.25	19	26
Beryllium Oxide	3	2	3	1	1	U	3	1	U	14	2	20	1.0	.25	1.25	17	25
Beryllium Powder	3	2	2	3	1	3	1	2	2	19		19	1.0	.25	1.25	24	24
Beryllium Selenate	3	2	3	3	1	U	3	1	U	16	2	22	1.0	.25	1.25	20	27
Boron Trichloride	2	2	2	2	2	U	2	2	U	14	2	20	1.0	.25	1.25	17	25
Boron Trifluoride	3	1	2	2	2	U	3	1	U	14	2	20	1.0	.25	1.25	17	25
Bromic Acid	3	2	U	3	1	U	3	2	U	14	3	23	1.0	.25	1.25	17	29
Bromine	3	2	U	2	2	3	3	2	U	17	2	23	1.5	.25	1.75	30	40
Bromine Pentafluoride	3	2	U	3	2	U	3	2	U	15	3	24	1.0	.25	1.25	19	30
Butadiene	2	2	3	2	U	3	1	1	U	14	2	20	1.5	.25	1.75	24	35
Butane	2	2	1	1	1	1	1	2	U	11	1	14	1.5	.5	2.0	22	28
Butanol (Butyl Alcohol)	1	2	1	2	1	3	1	2	U	13	1	16	1.5	.5	2.0	26	32
Butene - 1 (Ethyl Ethylene)	2	2	U	1	1	U	1	2	U	9	3	18	1.5	.25	1.75	16	31
Butylacetate (Butyl Ethanoate)	1	2	1	1	1	3	1	2	U	12	1	15	1.5	.5	2.0	24	30
Butylacrylate	1	2	1	2	1	2	1	2	U	12	1	15	1.25	.25	1.5	18	22

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(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
n-Butylamine	2	2	1	2	1	3	2	2	U	15	1	18	1.0	.25	1.25	19	22
Butyl Mercaptan	2	2	1	2	1	U	2	2	U	12	2	18	1.0	.25	1.25	15	22
Butyl Phenol	1	2	U	1	1	U	2	2	U	9	3	18	1.0	.25	1.25	11	22
Butyraldehyde (Butyl Aldehyde - n)	1	2	1	2	1	3	1	2	U	13	1	16	1.0	.25	1.25	16	20
Cacodylic Acid (Dimethylarsinic Acid)	3	2	1	3	1	U	2	2	2	16	1	19	1.0	.25	1.25	20	24
Cadmium	3	2	3	3	1	U	1	2	U	15	2	21	1.25	.5	1.75	26	37
Cadmium Chloride	3	2	3	3	1	3	3	2	3	23		23	1.0	.25	1.25	29	29
Cadmium Cyanide	3	2	2	3	2	2	1	2	2	19		19	1.0	.25	1.25	24	24
Cadmium Fluoride	3	2	3	3	1	U	3	1	U	16	2	22	1.0	.25	1.25	20	27
Cadmium Nitrate	3	2	U	3	1	3	3	2	3	20	1	23	1.0	.25	1.25	25	29
Cadmium Oxide	3	2	2	3	1	U	1	2	U	14	2	20	1.0	.5	1.5	21	30
Cadmium Phosphate	3	2	1	3	2	U	2	2	U	15	2	21	1.0	.25	1.25	19	26
Cadmium Potassium Cyanide	3	2	U	3	2	U	3	2	U	15	3	24	1.0	.25	1.25	19	30
Cadmium Sulfate	3	2	3	3	1	1	3	1	3	20		20	1.0	.25	1.25	25	25
Calcium Arsenate	3	2	2	3	2	3	2	2	U	19	1	22	1.0	.25	1.25	24	27
Calcium Arsenide	3	2	U	3	2	U	2	2	U	14	3	23	1.0	.25	1.25	17	29
Calcium Carbide	1	2	U	1	2	U	1	2	U	9	3	18	1.5	.25	1.75	16	31
Calcium Cyanide	3	2	3	3	2	U	1	2	U	16	2	22	1.25	.5	1.75	28	38
Calcium Fluoride	3	2	1	3	1	U	2	2	U	14	2	20	1.5	.25	1.75	24	35
Calcium Hydride	1	2	U	1	2	U	2	2	U	10	3	19	1.0	.25	1.25	12	24
Calcium Hypochlorite	2	2	U	2	2	3	2	2	U	15	2	21	1.5	.25	1.75	26	37
Calcium Oxide	3	1	U	2	2	2	2	1	U	13	2	19	1.5	.25	1.75	23	33
Carbon Disulfide	3	2	2	3	1	3	2	2	U	18	1	21	1.5	.25	1.75	31	37
Carbon Monoxide	3	2	3	1	1	3	1	1	U	15	1	18	1.5	.25	1.75	26	31
Carbon Tetrachloride	3	2	1	3	1	2	2	2	U	16	1	19	1.5	.25	1.75	28	33
Carbonyl Chloride (Phosgene)	3	2	3	3	2	U	3	2	U	18	2	24	1.0	.25	1.25	22	30
Chloral Hydrate	2	1	1	2	1	U	1	1	U	9	2	15	1.0	.25	1.25	11	19

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TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Chlorine	3	2	2	2	2	3	1	2	U	17	1	20	1.25	.25	1.5	30	35
Chlorine Trifluoride	3	3	3	3	2	U	3	3	U	20	2	26	1.0	.25	1.25	25	32
Chloroacetophenone	2	2	U	1	2	U	1	2	U	10	2	16	1.0	.5	1.5	15	24
Chlorobenzene (Chlorobenzol)	2	2	1	2	1	3	1	2	U	14	1	17	1.5	.25	1.75	24	30
Chlorodene	1	1	2	1	1	3	1	1	3	14		14	1.0	.25	1.25	17	17
Chloroform (Trichloromethane)	3	2	2	1	2	3	1	2	U	16	1	19	1.5	.25	1.75	28	33
Chlorosulfonic Acid	3	2	U	3	2	3	3	2	U	18	2	24	1.5	.25	1.75	31	42
Chromic Acid	3	2	2	3	1	3	3	2	U	19	1	22	1.25	.25	1.5	28	33
Chromic Fluoride	3	2	U	3	1	U	3	1	U	13	3	22	1.0	.25	1.25	16	27
Chromic Sulfate	3	2	2	3	1	3	3	1	3	21		21	1.0	.25	1.25	26	26
Chromium Cyanide	3	2	U	3	1	U	3	1	U	13	3	22	1.0	.25	1.25	16	27
Coal (Particle)	2	2	U	1	1	U	1	2	3	12	2	18	1.5	.5	2.0	24	36
Colbalt Chloride	1	2	3	1	1	3	2	1	3	17		17	1.0	.25	1.25	21	21
Cobaltous Nitrate	1	2	2	2	1	3	1	2	2	16		16	1.0	.5	1.5	24	24
Copper Acetoarsenite	3	2	3	3	1	U	2	2	U	16	2	22	1.0	.25	1.25	20	27
Copper Cyanide (Cuprous Cyanide)	2	2	U	2	2	U	1	2	U	11	3	20	1.0	.25	1.25	14	25
Copper Nitrate	2	3	3	2	1	3	1	2	U	17	1	20	1.0	.25	1.25	21	25
Copper Sulfate	2	2	2	2	1	3	2	2	2	18		18	1.5	.5	2.0	36	36
Creosote	2	2	1	2	1	2	2	2	U	14	1	17	1.5	.25	1.75	24	30
Cresol (Cresylic Acid)	2	2	2	2	1	3	2	2	U	16	1	19	1.5	.25	1.75	28	33
Crotonaldehyde	3	2	2	3	1	3	3	2	U	19	1	22	1.0	.25	1.25	24	27
Cumene (Isopropylbenzol)	3	2	1	3	1	3	2	2	U	17	1	20	1.5	.25	1.75	30	35
Cyanides	3	2	U	3	2	U	2	2	U	14	3	23	1.0	.25	1.25	17	29
Cyanoacetic Acid	3	2	U	3	2	U	2	2	U	14	3	23	1.0	.25	1.25	17	29
Cyclohexane (Hexanhydrobenzene)	1	2	1	1	1	3	1	2	U	12	1	15	1.5	.5	2.0	24	30
Cyclohexanol (Hexalin)	1	2	1	2	1	3	1	2	U	13	1	16	1.5	.25	1.75	23	28
Cyclohexanone	1	2	1	1	1	3	1	2	U	12	1	15	1.5	.25	1.75	21	26

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(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Cyclohexylamine	3	2	2	2	1	U	2	2	U	14	2	20	1.25	.25	1.5	21	30
Demeton	3	1	3	3	1	3	3	1	3	21		21	1.0	.25	1.25	26	26
Decyl Alcohol	1	2	U	1	1	1	1	2	U	9	2	15	1.5	.25	1.75	16	26
Dibutyl Phthalate - n	1	1	U	2	1	1	1	1	U	8	2	14	1.25	.25	1.5	14	24
o - Dichlorobenzene	2	2	1	2	1	3	2	2	U	15	1	18	1.25	.25	1.5	22	27
p - Dichlorobenzene	1	2	U	2	1	3	1	2	U	12	2	18	1.25	.25	1.5	18	27
2, 4 - Dichlorophenoxyacetic Acid (2, 4-D)	2	2	2	2	1	3	2	2	2	18		18	1.25	.25	1.5	27	27
DDD (Dichloro Diphenyl Dichloro Ethene)	1	2	2	2	1	3	1	1	U	13	1	16	1.0	.25	1.25	16	20
DDT (Dichloro DiPhonyl-Trichloroethane)	3	1	2	2	1	3	3	1	3	19		19	1.25	.25	1.5	28	28
Diborane (Boron Hydride)	3	3	3	3	2	U	3	3	U	20	2	26	1.0	.25	1.25	25	32
Dichloroethyl Ether	3	2	U	3	2	3	1	2	U	16	2	22	1.0	.25	1.25	20	27
Dichloromethane (Methylene Chloride)	1	1	2	2	1	2	2	2	U	13	1	16	1.5	.25	1.75	23	28
1, 2 - Dichloropropane	3	2	1	3	1	3	3	2	U	18	1	21	1.25	.25	1.5	27	31
1, 3 - Dichloropropene	2	2	2	2	1	3	3	2	U	17	1	20	1.0	.25	1.25	21	25
Dieldrin	3	2	3	3	1	3	3	2	U	20	1	23	1.0	.25	1.25	25	29
Diethanolamine	1	1	1	1	1	2	1	2	U	10	1	13	1.25	.25	1.5	15	19
Diethylamine	2	2	1	3	1	2	2	2	U	15	1	18	1.0	.25	1.25	19	22
Diethyl Ether (Ethyl Ether)	2	2	1	2	1	U	1	2	U	11	2	17	1.5	.25	1.75	19	30
Diethylene Dioxide (1, 4 - Dioxane)	3	2	1	3	1	U	2	2	U	14	2	20	1.0	.25	1.25	17	25
Diethylene Triamine	2	2	1	2	1	2	2	1	U	13	1	16	1.0	.25	1.25	16	20
Diethylotilbestrol	2	1	1	2	1	U	2	1	U	10	2	16	1.0	.25	1.25	12	20
Diisobutylene	1	2	U	1	1	1	1	2	U	9	2	15	1.25	0	1.25	11	19
Diisobutyl Ketone	1	1	2	1	1	2	1	2	U	11	1	14	1.0	0	1.0	11	14
Dimethylamine	2	2	1	2	1	3	2	2	U	15	1	18	1.25	.25	1.5	22	27
Dimethyl Sulfate (Methyl Sulfate)	3	2	3	3	1	U	3	2	U	17	2	23	1.0	.25	1.25	21	29
2, 4 - Dinitroaniline	2	2	U	3	1	U	2	1	U	11	3	20	1.5	.5	2.0	22	40
Dinitro - o - Cresols	3	3	3	3	1	3	3	3	U	22	1	25	1.0	.25	1.25	27	31

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TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
o - Dinitrobengol (1, 2 - Dinitrobenzene)	3	3	U	3	2	3	3	2	U	19	2	25	1.0	.25	1.25	24	31
2, 4 - Dinitrophenol	3	3	3	3	1	3	2	3	U	21	1	24	1.0	.5	1.5	31	36
2, 4 - Dinitrotoluene (Dinitrotoluol)	3	3	U	3	1	3	2	2	U	17	2	23	1.5	.25	1.75	30	40
Diphenylamine (Phenylaniline)	3	2	2	3	1	U	1	1	U	13	2	20	1.25	.25	1.5	19	30
Dipropylene Glycol	1	2	1	2	1	1	1	1	U	10	1	13	1.25	.25	1.5	15	19
Dodecyl Benzene (Crude)	U	2	U	U	1	2	U	3	U	8	5	23	1.5	.25	1.75	14	40
Endrin	3	2	2	3	1	3	3	1	3	21		21	1.0	.25	1.25	26	26
Epichlorohydrin	3	2	2	3	1	3	3	2	U	19	1	22	1.5	.25	1.75	33	38
Ethane	2	2	1	1	1	U	1	1	U	9	2	15	1.5	.25	1.75	16	26
Ethanol (Ethyl Alcohol)	2	2	1	2	1	1	1	2	U	12	1	15	1.5	.25	1.75	21	26
Ethanolamine (Monoethanolamine)	2	2	1	2	1	2	2	1	U	13	1	16	1.5	.25	1.75	23	28
Ethers	1	2	1	1	1	U	1	2	U	9	2	15	1.5	.25	1.75	16	26
Ethyl Acetate (Acetic Ether)	1	2	1	2	1	1	1	2	U	11	1	14	1.5	.25	1.75	19	24
Ethyl Acrylate	3	2	1	3	1	2	3	2	U	17	1	20	1.5	.25	1.75	30	35
Ethylamine (Monoethylamine)	3	2	2	3	1	3	3	2	U	19	1	22	1.25	.25	1.5	28	33
Ethyl Benzene (Phenyl Ethane)	2	1	1	2	1	3	2	1	U	13	1	16	1.6	.25	1.75	23	28
Ethyl Chloride (Chloroethane)	2	2	U	2	2	1	1	2	U	12	2	18	1.5	.25	1.75	21	31
Ethylene (Ethene)	2	2	2	1	1	3	1	2	U	14	1	17	1.25	.25	1.5	21	25
Ethylene Bromide (Ethylene Dibromide)	3	2	2	3	1	3	3	2	U	19	1	22	1.0	.5	1.5	28	33
Ethylene Cyanohydrin	2	2	U	2	2	1	1	2	U	12	2	18	1.0	.25	1.25	15	22
Ethylene Diamine	2	2	1	2	1	3	2	1	U	14	1	17	1.25	.25	1.5	21	25
Ethylene Dibromide (Dibromethane)	2	2	3	3	1	3	2	2	U	18	1	21	1.0	.25	1.25	22	26
Ethylene Dichloride (1, 2-Dichloroethane)	3	2	1	3	1	2	2	2	U	16	1	19	1.5	.25	1.75	28	33
Ethylene Glycol (Glycol)	1	2	1	2	1	1	1	1	U	10	1	13	1.5	.25	1.75	17	23
Ethylene Glycol Monoethyl Ether	1	2	1	2	1	2	1	2	U	12	1	15	1.0	.5	1.5	18	22
Ethylene Glycol Monoethyl Ether Acetate	2	2	1	2	1	2	1	1	U	12	1	15	1.0	.25	1.25	15	19
Ethylene Oxide	2	2	1	1	1	2	2	2	U	13	1	16	1.5	.25	1.75	23	28

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(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Ethylenimine	3	2	3	3	1	3	3	2	U	20	1	23	1.25	.25	1.5	30	34
2-Ethylhexanol (Octyl Alcohol)	2	1	1	1	1	U	1	2	U	9	2	15	1.5	.25	1.75	16	26
Ethyl Mercaptan	2	2	U	2	2	U	2	2	U	12	3	21	1.0	.25	1.25	15	26
Ethyl Methyl Ketone (Butanone)	2	2	1	1	1	1	1	2	U	11	1	14	1.0	.5	1.5	16	21
Ethyl Phthalate (Diethyl o-Phthalate	2	1	1	2	1	3	2	1	U	13	1	16	1.0	.25	1.25	16	20
2-Ethyl - 3 Propyl Acrolein	2	2	U	2	1	2	2	1	U	12	2	18	1.0	.25	1.25	15	22
Ferrous Sulfate	1	1	2	1	1	3	1	1	U	11	1	14	1.5	.5	2.0	22	28
Fluorides (e. g., Hydrogen Fluoride, etc.)	3	2	3	3	1	U	3	2	U	17	2	23	1.5	.25	1.75	30	40
Fluorine (Hydrofluoric Acid)	3	2	3	3	1	3	3	2	U	20	1	23	1.5	.25	1.75	35	40
Formaldehyde - 37% Solution	3	2	2	3	1	3	3	2	U	19	1	22,	1.5	.5	2.0	38	44
Formic Acid	3	2	2	3	1	1	2	1	1	16		16	1.25	.25	1.5	24	24
Furfural (Furfuraldehyde)	2	2	2	2	1	3	2	1	U	15	1	18	1.5	.25	1.75	26	31
Furfural Alcohol	2	2	2	U	1	3	U	1	U	11	3	20	1.25	.25	1.5	16	35
Guthion	3	2	3	3	1	3	3	1	3	22		22	1.0	.25	1.25	27	27
Heptalchor	2	2	3	2	1	3	1	1	3	18		18	1.0	.25	1.25	22	22
Heptane (Heptyl Hydride)	2	2	2	1	1	2	1	1	U	12	1	15	1.5	.25	1.75	15	19
Hexachlorophene (Methylene)	1	2	3	1	1	U	3	1	U	12	2	18	1.0	.25	1.25	15	22
Hexaethyitetraphosphate	3	2	3	3	1	3	3	2	U	20	1	23	1.0	.25	1.25	25	29
Hexamethylene Diamine	2	1	U	2	1	U	2	1	U	9	3	18	1.5	.25	1.75	16	31
Hexane (Hexyl Hydride)	1	2	1	1	1	1	1	1	U	9	1	12	1.5	.25	1.75	16	21
Hydrazine (Anhydrous Diamine)	3	3	2	3	1	3	3	3	U	21	1	24	1.0	.25	1.25	26	30
Hydrobromic Acid	3	2	U	3	2	U	3	2	U	15	3	24	1.0	.25	1.25	19	30
Hydrochloric Acid (Muriatic Acid)	3	2	1	3	1	3	3	2	U	18	1	21	1.5	.5	2.0	36	42
Hydrocyanic Acid (Hydrogen Cyanide)	3	3	[illegible]	3	2	3	3	3	U	22	1	25	1.5	.5	2.0	44	50
Hydrofluoric Acid (Hydrogen Fluoride)	3	2	3	3	2	3	3	3	U	21	1	24	1.5	.25	1.75	37	42
Hydrogen Chloride Anhydrous	3	1	U	3	1	3	3	1	3	18	1	21	1.5	.25	1.75	31	37
Hydrogen Peroxide (over 52%)	3	3	2	3	1	3	3	3	U	21	1	24	1.5	.25	1.75	37	42

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(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
p - Hydroquinone	2	1	2	2	1	3	2	1	U	14	1	17	1.25	.5	1.75	24	30
Hydrogen Sulfide	3	2	3	3	1	3	3	2	2	22		22	1.5	.25	1.75	38	38
Iodine	3	2	U	3	1	3	3	2	U	15	2	21	1.0	.5	1.5	22	31
Isobutyl Acetate	2	1	1	2	1	3	2	2	U	14	1	17	1.0	.25	1.25	17	21
Isobutyl Alcohol	2	2	1	2	2	U	3	2	U	14	2	20	1.0	.5	1.5	21	30
Isophorone	3	U	1	3	U	3	3	U	U*	13	4	25	1.0	.25	1.25	16	31
Isoprene	2	1	2	2	1	3	2	2	U	15	1	18	1.5	.25	1.75	26	31
Isopropanol (Isopropyl Alcohol)	2	2	1	2	1	2	1	2	U	13	1	16	1.5	.25	1.75	23	28
Isopropyl Acetate	2	2	1	2	1	1	1	2	U	12	1	15	1.25	.25	1.5	21	26
Isopropylamine	3	1	2	3	1	3	3	2	U	18	1	21	1.25	.25	1.5	31	37
Isopropyl Ether	2	2	1	2	1	2	3	3	U	16	1	19	1.25	.25	1.5	24	28
Lead	3	2	2	3	1	U	1	2	U	14	2	20	1.5	.5	2.0	28	40
Lead Acetate	3	2	2	3	1	3	3	2	2	21		21	1.25	.25	1.5	31	31
Lead Arsenate	3	2	2	3	1	3	3	1	3	21		21	1.5	.25	1.75	37	37
Lead Arsenite	3	2	3	3	1	U	3	1	U	16	2	22	1.25	.25	1.5	24	33
Lead Carbonate	3	2	2	3	1	U	3	1	U	15	2	21	1.25	.25	1.5	22	31
Lead Chlorite	3	2	U	3	1	U	3	2	U	14	3	23	1.25	.25	1.5	21	34
Lead Cyanides	3	2	2	3	2	U	3	2	3	20	1	23	1.25	.25	1.5	30	34
Lead Nitrate	3	3	2	3	1	3	3	3	3	24		24	1.25	.25	1.5	36	36
Lead Nitrite	3	2	U	3	1	U	3	2	U	14	3	23	1.25	.25	1.5	21	34
Lead Oxide	3	2	2	3	1	U	3	2	U	16	2	22	1.25	.5	1.75	28	38
Lithium Aluminum Hydride	2	2	U	2	2	U	2	2	U	12	3	21	1.0	.25	1.25	15	26
Magnesiumo-Arsenite	3	2	U	3	2	U	2	2	U	14	3	23	1.0	.25	1.25	17	29
Magnesium Chlorate	2	2	1	2	1	U	2	2	U	12	2	18	1.0	.25	1.25	15	22
Magnesium Sulfate	2	1	1	1	1	1	2	1	U	10	1	13	1.5	.5	2.0	20	26
Maleic Anhydride	3	2	3	3	2	3	3	2	U	21	1	24	1.5	.5	2.0	42	48
Manganese	3	2	U	1	1	U	1	1	U	9	3	18	1.0	.25	1.25	11	22

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(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Manganese Arsenate	3	2	3	3	1	U	2	1	U	15	2	21	1.0	.25	1.25	19	26
Manganese Chloride	3	2	3	3	1	2	1	1	U	16	1	19	1.0	.25	1.25	20	29
Manganese Cyclopentadienyltricarbonyl	3	2	3	3	1	U	1	1	U	14	2	20	1.0	.25	1.25	17	25
Mercuric Chloride	3	2	3	3	1	3	3	2	U	20	1	23	1.0	.5	1.5	30	34
Mercuric Cyanide	3	2	U	3	1	3	3	2	U	17	2	23	1.0	.25	1.25	21	29
Mercuric Diammonium Chloride	3	2	U	3	1	U	3	2	U	14	3	23	1.0	.25	1.25	17	29
Mercuric Nitrate	3	3	U	3	1	3	3	3	U	19	2	25	1.0	.25	1.25	24	31
Mercuric Sulfate	3	2	U	3	1	U	3	1	U	13	3	22	1.0	.5	1.5	19	33
Mercury	3	2	U	3	1	3	3	1	U	16	2	22	1.0	.5	1.5	24	33
Mercury Compounds (Organic)	3	2	3	3	1	3	3	1	U	19	1	22	1.0	.25	1.25	24	27
Mesityl Oxide	3	2	1	3	1	3	3	1	U	17	1	20	1.0	.25	1.25	21	25
Methanol (Methyl Alcohol)	2	2	2	3	1	2	2	2	U	16	1	19	1.5	.5	2.0	32	38
Methyl Acetate	2	2	1	2	1	1	1	1	U	11	1	14	1.25	.25	1.5	16	21
Methyl Acrylate (Acrylic Esters)	3	2	3	3	1	2	3	2	U	19	1	22	1.0	.5	1.5	28	33
Methylamine (30% Solution)	3	2	2	3	1	3	3	1	U	18	1	21	1.5	.25	1.75	31	37
Methyl Amyl Alcohol	3	2	2	3	1	2	3	1	U	17	1	20	1.0	.25	1.25	21	25
Methyl Bromide (Bromomethane)	3	2	2	3	1	1	3	2	3	20		20	1.25	.25	1.5	30	30
Methyl Chloride (Chloromethane)	2	2	U	2	1	1	1	2	U	11	2	17	1.5	.25	1.75	19	30
Methyl Chloroformate	3	2	U	3	2	U	3	1	U	14	3	23	1.0	.25	1.25	17	29
Methyl Formate (Methyl Methanoate)	2	2	1	2	1	2	2	2	1	15		15	1.0	.25	1.25	19	19
Methyl Isobutyl Ketone (Hexone)	2	2	1	2	1	1	2	1	U	12	1	15	1.0	.25	1.25	15	19
Methyl Mercaptans (Methanethiol)	2	2	2	2	2	3	2	2	U	17	1	20	1.0	.25	1.25	21	25
Methyl Methacrylate Monomer	2	2	U	1	1	2	2	2	U	12	2	18	1.5	.25	1.75	21	31
Methyl Parathion	3	2	3	3	1	3	3	2	U	20	1	23	1.25	.25	1.5	30	34
Monomethylaniline (n-Methylanilins)	3	2	2	3	1	U	3	2	U	16	2	22	1.0	.25	1.25	20	27
Morpholine	2	2	2	2	1	2	2	1	U	14	1	17	1.25	.25	1.5	21	25
Naphtha (Crude)	2	1	U	3	1	2	3	1	2	15	1	18	1.0	.25	1.25	19	22

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(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Total Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Naphthalene (Naphthaline)	2	2	2	2	1	3	2	1	1	15	1	18	1.5	.25	1.75	26	31
Naphthylamine – beta	3	2	2	3	1	1	3	2	1	16	2	22	1.0	.25	1.25	20	27
Nickel	2	1	2	2	1	2	1	1	2	14		14	1.25	.25	1.5	24	24
Nickel Ammonium Sulfate	2	2	1	1	1	3	2	1	3	15	1	18	1.0	.25	1.25	19	22
Nickel Antimonide	3	2	1	3	2	1	3	2	1	15	3	24	1.0	.25	1.25	19	30
Nickel Arsenide	3	2	1	3	2	1	2	2	1	14	3	23	1.0	.25	1.25	17	29
Nickel Carbonyl	3	2	3	1	1	3	1	2	3	19		19	1.0	.5	1.5	28	28
Nickel Chloride	2	2	3	1	1	3	2	1	3	18		18	1.0	.5	1.5	27	27
Nickel Cyanide	3	2	1	3	2	1	2	2	3	17	2	23	1.0	.25	1.25	21	29
Nickel Nitrate	2	3	2	2	1	3	2	3	3	21		21	1.0	.25	1.25	26	26
Nickel Selenide	3	2	1	2	2	1	2	2	1	13	3	22	1.0	.25	1.25	16	27
Nickel Sulfate	2	2	3	1	1	3	2	1	[illegible]	17		17	1.25	.5	1.75	30	30
Nitric Acid	3	1	3	3	2	3	3	1	2	21		21	1.5	25	1.75	37	37
Nitroanilene (Nitraneline - meta-para)	3	3	1	3	1	3	3	3	1	19	2	25	1.25	.5	1.75	33	44
Nitrobenzene (Nitrobenzol)	3	3	2	3	1	3	3	3	1	21	1	24	1.5	.25	1.75	37	42
Nitrochlorobenzine (meta or para)	3	2	1	3	1	1	3	1	1	13	3	22	1.5	.25	1.75	23	38
Nitroethane	2	3	1	2	1	1	2	3	1	14	2	20	1.0	.25	1.25	17	25
Nitroglycerin	3	3	3	3	1	1	2	3	1	18	2	24	1.0	25	1.25	22	30
Nitromethane	3	2	3	3	1	1	1	2	1	15	2	21	1.0	.25	1.25	19	26
Nitroparaffins	2	2	1	2	1	1	1	1	1	9	3	18	1.0	.25	1.25	11	22
p - Nitrophenol	3	3	3	3	1	3	1	2	1	19	1	22	1.25	.25	1.5	28	33
Nitropropane (1 and 2)	2	3	2	2	1	3	1	2	1	16	1	19	1.0	.25	1.25	20	24
p - Nitrotoluol (Nitrotoluene)	2	2	1	2	1	3	2	2	1	14	1	17	1.25	25	1.5	21	25
Nitrous Oxide	2	2	1	1	1	1	1	2	1	10	2	16	1.25	.25	1.5	15	24
Oxalic Acid	3	1	3	3	1	3	3	2	1	19	1	22	1.25	25	1.5	28	33
Paraformaldehyde	2	2	2	3	1	1	2	1	1	13	2	32	1.0	.5	1.5	19	28
Parathion	3	2	3	3	1	3	3	2	1	20	1	23	1.25	25	1.5	30	31

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(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Pentaborane	3	3	3	3	1	U	3	3	3	22	1	25	1.0	.25	1.25	27	31
Pentachlorophenol	3	2	3	3	1	3	3	1	3	22		22	1.25	.5	1.75	38	38
PETN (Pentaerythritol Tetranitrate)	2	3	U	2	1	U	2	3	U	13	3	22	1.0	.25	1.25	16	27
n - Pentane (Amyl Hydride)	1	2	1	1	1	2	1	2	U	11	1	14	1.0	.5	1.5	16	21
Perchloric Acid (≤ 72%)	3	2	U	3	1	3	3	2	U	17	2	23	1.5	.25	1.75	30	40
Perchloroethylene (Tetrachloroethylene)	2	2	U	3	1	3	2	1	U	14	2	20	1.5	.5	2.0	28	40
Perchloryl Fluoride	2	2	3	2	1	U	2	2	U	14	2	20	1.0	.25	1.25	17	25
Phenol (Carbolic Acid)	3	2	2	3	1	3	3	2	U	19	1	22	1.5	.5	2.0	38	44
Phenylhydrogine Hydrochloride	3	2	2	3	1	U	2	2	U	15	2	21	1.0	.25	1.25	19	26
Phosphoric Acid	2	2	U	2	1	3	2	1	U	13	2	22	1.5	.5	2.0	26	44
Phosphorus (Red)	1	2	U	1	1	U	1	2	U	8	2	14	1.5	.25	1.75	14	24
Phosphorus (White or Yellow)	3	3	U	3	3	3	3	3	U	21	2	27	1.5	.25	1.75	37	47
Phosphorus Oxychloride	3	2	U	3	2	U	3	2	U	15		15	1.25	0	1.25	19	19
Phosphorus Pentachloride	3	2	3	3	2	U	3	2	U	18	2	24	1.0	.25	1.25	22	30
Phosphorus Pentasulfide	3	2	U	1	2	U	2	2	U	12	3	21	1.5	.25	1.75	21	37
Phosphorus Trichloride	3	2	U	3	2	3	3	2	U	15	2	21	1.5	.25	1.75	26	37
Phthalic Acid (Terephthalic Acid)	1	1	2	1	1	3	1	1	U	11	1	14	1.5	.25	1.75	19	24
Picric Acid (Trinetrophenol)	2	3	2	3	1	3	2	3	U	20	1	23	1.0	.25	1.25	25	29
Polychlorinated Biphenyls (Askarels)	3	2	U	2	1	U	2	1	U	11	3	20	1.0	.25	1.25	14	25
Potassium Arsenite	3	2	3	3	1	3	2	2	U	19	1	22	1.5	.25	1.75	33	38
Potassium Binoxalate	1	2	U	3	1	U	3	1	U	11	3	20	1.0	.25	1.25	14	25
Potassium Chromate	3	1	3	3	1	3	3	1	3	21		21	1.5	.25	1.75	37	37
Potassium Cyanide (Solid)	3	2	3	3	2	3	2	2	U	20	1	23	1.5	.5	2.0	40	46
Potassium Dichromate	3	1	U	3	1	3	3	1	3	18	1	21	1.5	.5	2.0	36	42
Potassium Fluoride	3	2	2	3	1	1	3	2	U	15	1	18	1.5	.5	2.0	30	36
Potassium Hydroxide (Caustic Potash)	3	2	2	3	2	3	3	2	U	20	1	23	1.5	.25	1.75	35	40
Potassium Oxalate	1	2	U	3	1	U	1	1	U	9	3	18	1.0	.5	1.5	13	27

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(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Total Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Potassium Permanganate	3	2	3	3	1	3	3	2	U	20	1	23	1.5	.5	2.0	40	46
Potassium Peroxide	2	2	U	2	2	3	2	2	U	15	2	21	1.5	.25	1.75	26	37
Potassium Sulfate	1	2	2	3	1	2	2	1	U	14	1	17	1.5	.25	1.75	24	30
Potassium Sulfide	3	2	U	3	2	3	3	2	U	18	2	24	1.5	.25	1.75	31	42
Propane (L. P. Gas)	1	2	U	1	1	1	1	1	U	8	2	14	1.5	.5	2.0	16	28
Propionaldehydl (Propyl Aldehyde)	2	1	2	2	1	2	2	2	U	14	1	17	1.0	.25	1.25	17	21
Propionic Acid	2	1	2	1	1	2	1	2	U	12	1	15	1.25	.25	1.5	18	22
n - Propyl Acetate	2	2	U	2	1	2	1	1	U	11	2	17	1.25	.25	1.5	16	25
n - Propyl Alcohol	1	2	1	1	1	2	1	1	U	10	1	13	1.25	.25	1.5	15	19
Propylamine	3	2	2	3	1	3	3	1	U	18	1	21	1.25	.25	1.5	27	31
Propylene	2	1	U	1	1	1	1	2	U	9	2	15	1.5	.5	2.0	18	30
Propylene Glycol	1	2	1	1	1	1	1	1	U	9	1	12	1.5	.25	1.75	16	21
Propylene Oxide	2	2	2	2	1	1	2	2	U	14	1	17	1.5	.25	1.75	24	30
Propylene Dichloride (Dichloropropane)	3	1	1	3	1	3	3	2	U	17	1	20	1.25	.25	1.5	25	30
Pyridine	2	2	1	2	1	2	1	2	U	13	1	16	1.25	.5	1.75	23	28
Quinone	3	2	2	3	1	3	3	1	U	18	1	21	1.0	.5	1.5	27	31
Salicylic Acid	1	1	1	2	1	1	1	1	U	9	1	12	1.25	.5	1.75	16	21
Selenium Powder	3	2	3	2	1	3	2	3	U	19	1	22	1.0	.5	1.5	28	33
Silicon Tetrochloride	3	2	3	3	2	U	3	2	U	18	2	24	1.0	.5	1.5	27	36
Silver Cyanides	3	2	U	3	2	U	2	2	U	14	3	23	1.0	.5	1.5	21	34
Sodium	3	2	U	3	2	U	2	2	U	14	3	23	1.5	.25	1.75	24	40
Sodium Amide (Sodamide)	2	2	U	3	2	U	3	2	U	14	3	23	1.5	.25	1.75	24	40
Sodium Arsenate	3	2	3	3	1	2	2	1	U	17	1	20	1.5	.5	2.0	34	40
Sodium Arsenite	3	2	3	3	1	3	2	1	3	21		21	1.5	.25	1.75	37	37
Sodium Azide	2	2	3	3	1	3	3	3	U	20	1	23	1.5	.25	1.75	35	40
Sodium Bichromate (Sodium Dicromate)	3	1	U	3	1	3	3	1	U	15	2	21	1.5	.5	2.0	30	42
Sodium Bisulfite	2	2	3	2	2	2	1	2	U	16	1	19	1.5	.5	2.0	32	38

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(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Sodium Borate	2	2	U	2	1	2	2	1	U	12	2	18	1.5	.25	1.75	21	31
Sodium Cacodylate	3	1	2	3	1	U	2	2	U	14	2	20	1.5	.25	1.75	24	35
Sodium Carbonate	2	1	1	2	1	3	2	1	1	14		14	1.5	.25	1.75	24	24
Sodium Carbonate Peroxide	2	2	U	2	1	U	2	2	U	11	3	20	1.5	.25	1.75	19	35
Sodium Chlorate	2	1	1	2	1	1	2	1	3	14		14	1.5	.5	2.0	28	28
Sodium Chromate	3	1	3	3	1	2	3	1	U	17	1	20	1.5	.25	1.75	30	35
Sodium Cyanide	3	2	3	3	2	3	2	2	U	20	1	23	1.5	.25	1.75	35	40
Sodium Fluoride	3	2	3	3	1	3	3	1	2	21		21	1.25	.5	1.75	37	37
Sodium Formate	3	1	U	3	1	2	3	1	U	14	2	20	1.5	.5	2.0	28	40
Sodium Hydride (Crystals)	3	2	U	3	2	U	2	2	U	14	3	23	1.5	.25	1.75	24	40
Sodium Hydrosulfite	2	2	U	2	2	3	1	2	U	14	2	20	1.25	.25	1.5	21	30
Sodium Hydroxide (Caustic Soda)	2	2	1	2	2	3	3	2	U	17	1	20	1.5	.5	2.0	34	40
Sodium Iodide	2	2	2	2	1	3	1	1	U	14	1	17	1.5	0	1.5	21	25
Sodium Nitrate (Solid)	2	2	3	2	1	1	1	2	U	14	1	17	1.5	.25	1.75	24	30
Sodium Nitrite (Solid)	3	U	2	3	U	3	1	U	U	12	4	24	1.5	.5	2.0	24	48
Sodium Oxalate	1	2	3	3	1	1	3	1	U	15	1	18	1.5	.5	2.0	30	36
Sodium Oxide	2	1	2	3	2	3	3	2	U	18	1	21	1.5	.25	1.75	31	37
Sodium Perchlorate	2	2	2	2	1	3	2	2	U	16	1	19	1.5	.25	1.75	28	33
Sodium Peroxide	3	2	1	3	2	3	2	2	U	17	2	23	1.5	.25	1.75	30	40
Sodium Phosphate	U	2	2	3	1	U	2	1	U	11	3	20	1.5	.5	2.0	22	40
Sodium-Potassium Alloy	2	2	U	2	1	U	2	2	U	11	3	20	1.5	.25	1.75	19	35
Sodium Sulfide	1	2	3	3	2	3	2	3	U	19	1	22	1.5	.5	2.0	38	44
Sodium Sulfite	2	2	2	2	2	2	1	2	U	15	1	18	1.5	.5	2.0	30	36
Sodium Thiocyanate (Sodium Sulfocyanide)	1	2	2	3	1	U	1	1	U	11	2	17	1.5	.25	1.75	19	30
Stannic Chloride	3	1	U	3	2	U	3	2	U	14	3	23	1.0	.25	1.25	17	29
Stannous Chloride	2	2	3	2	1	U	2	1	U	13	2	19	1.0	.25	1.25	16	24
Strontium	2	2	U	2	2	U	2	2	U	12	3	21	1.25	.25	1.5	18	31

Table IV-18
(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Styrene (Phenyl Ethylene)	2	2	1	2	1	3	2	1	U	14	1	17	1.5	.5	2.0	28	34
Sulfur Dioxide	3	2	2	3	2	3	3	2	3	23		23	1.5	.25	1.75	40	40
Sulfur Trioxide	3	2	U	3	2	U	3	2	U	15	3	24	1.0	.25	1.25	19	30
Sulfuric Acid	3	2	2	3	2	3	3	2	U	20	1	23	1.5	.5	2.0	40	46
Sulfurous Acid	3	2	U	3	1	U	3	1	U	13	3	22	1.0	25	1.25	16	27
Sulfuryl Fluoride	3	2	3	1	2	U	2	2	U	15	2	21	1.0	.25	1.25	19	26
Tantalum	2	2	U	1	1	U	2	1	U	9	3	18	1.0	.5	1.5	13	22
Tar (Liquid)	3	2	U	3	1	U	3	1	U	13	3	22	1.5	.5	2.0	26	44
Tear Gas (CN)	2	2	U	1	1	U	3	2	U	12	3	21	1.0	.25	1.25	15	26
Tetrachioroethane (Acetylene Tetrachloride)	3	2	3	3	1	U	2	2	U	16	2	22	1.0	.25	1.25	20	27
Tetraethyl Lead	3	2	3	3	1	3	3	2	3	23		23	1.5	.25	1.75	40	40
Tetrahydrofuran	3	2	U	3	1	U	3	2	U	14	3	23	1.0	.5	1.5	21	29
Tetramethyl Lead	3	2	2	3	1	U	3	2	3	19	1	22	1.25	.25	1.5	28	33
Tetranitromethane	3	3	3	3	1	U	3	3	U	19	2	24	1.0	.25	1.25	24	30
Thallium	3	2	3	3	1	U	1	1	U	14	2	20	1.0	.5	1.5	21	30
Thallium Sulfate	3	2	3	3	1	U	1	1	2	16	1	19	1.0	.5	1.5	24	28
Titanium Tetrachloride	3	2	U	1	2	3	3	2	3	19	1	22	1.0	.25	1.25	24	27
Toluene (Tolyol)	2	2	1	2	1	3	2	2	U	15	1	18	1.5	.5	2.0	30	36
Toluene Disocyanate	3	2	1	3	1	U	3	1	U	14	2	20	1.0	.25	1.25	17	25
Toluidine - o (2, 4-methylanilene)	3	2	2	2	1	2	2	1	U	16	1	19	1.0	.25	1.25	20	24
Trichlorobenzene	2	1	U	2	1	3	1	1	1	12	1	15	1.25	.25	1.5	18	22
Trichloroethane (α or β)	2	2	2	2	1	3	1	2	U	15	1	18	1.5	.25	1.75	26	31
Trichloroethylene	3	2	1	2	1	2	2	2	U	15	1	18	1.5	.25	1.75	26	31
Trichlorofluoromethane (Freon 11)	1	2	U	1	1	2	1	2	U	10	1	13	1.5	.25	1.75	17	23
Triethanolamine	1	2	1	1	1	3	1	1	U	11	1	14	1.25	25	1.5	16	21
Triethylamine	3	2	2	3	1	3	3	2	U	19	1	22	1.0	.5	1.5	28	33
Triethylene Glycol	1	2	2	2	1	1	1	1	U	11	1	14	1.25	.5	1.75	19	24

Table IV-18
(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Triethylene Tetramine	3	1	U	3	1	3	3	1	U	15	2	21	1.0	.25	1.25	19	26
Trimethylamine	2	2	U	1	1	2	1	1	U	10	2	16	1.25	.25	1.5	15	24
Tri-o-Cresyl Phosphate	2	2	U	3	1	U	2	1	U	11	3	20	1.25	.25	1.5	16	30
Turpentine	1	2	U	2	1	3	1	1	U	11	2	17	1.5	.5	2.0	22	34
Vanadium Pentoxide	3	2	3	1	1	U	1	1	3	15	1	18	1.0	.25	1.25	19	22
Vanadium Sulfide	2	2	3	1	1	U	1	1	U	11	2	17	1.0	.25	1.25	14	21
Vinyl Acetate	1	2	3	1	1	3	1	1	U	13	1	16	1.5	.25	1.75	23	28
Vinyl Chloride	2	2	U	2	1	1	2	2	U	12	2	18	1.5	.25	1.75	21	31
m - Xylene (Xylox)	1	2	1	1	1	3	1	1	1	12		12	1.5	.25	1.75	21	21
Xylenol (3, 5-Dimethylphenol)	3	1	2	3	1	3	3	1	U	17	1	20	1.25	.25	1.5	25	30
Zinc Arsenate	3	2	U	3	1	U	2	1	U	12	3	21	1.0	.25	1.25	15	26
Zinc Arsenite	3	2	U	3	1	U	2	1	U	12	3	21	1.0	.25	1.25	15	25
Zinc Chloride	2	2	3	1	1	3	2	2	U	16	1	19	1.25	.5	1.75	28	33
Zinc Cyanide	3	2	U	3	2	U	2	2	U	14	3	23	1.0	.25	1.25	17	29
Zinc Nitrate	2	3	U	2	1	3	1	3	U	15	2	21	1.0	.5	1.5	22	26
Zinc Oxide	2	1	3	1	1	3	1	1	U	13	1	16	1.5	.5	2.0	26	32
Zinc Permanganate	3	2	U	3	1	U	1	1	U	11	3	20	1.0	.25	1.25	14	25
Zinc Peroxide	2	2	U	1	2	3	1	2	U	13	2	19	1.0	.25	1.25	16	24
Zinc Sulfide	2	2	U	1	2	U	1	2	U	10	3	19	1.0	.25	1.25	12	24

Table IV-19
Compounds Found Marginally Hazardous by Rating System

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Adipic Acid	U	1	1	U	1	2	U	1	U	6	4	18	1.5	.25	1.75	10	31
Aminoethylethanolamine	1	1	U	U	1	1	2	1	U	7	3	16	1.0	.25	1.25	9	20
Bismuth	1	2	U	1	1	U	1	2	U	8	3	17	1.0	.25	1.25	10	21
Boric Acid	2	U	1	2	U	1	1	U	U	7	4	19	1.5	.5	2.0	14	38
Calcium Chloride	1	2	1	1	1	2	1	2	U	11	1	14	1.5	.25	1.75	19	24
Calcium Phosphate	U	2	U	U	1	U	U	2	U	5	6	23	1.5	.5	2.0	10	46
Camphor	1	2	1	2	1	1	1	2	U	11	1	14	1.0	.25	1.25	14	17
Citric Acid	1	1	1	1	1	2	1	1	U	9	1	12	1.5	.25	1.75	16	21
Copper (Dust)	2	2	U	2	1	U	1	1	U	9	3	18	1.5	.25	1.75	16	31
Dichlorodifluoromethane (Freon 12)	1	2	U	1	1	1	1	2	U	9	2	15	1.5	.25	1.75	16	26
Dichlorotetrafluoroethane (Freon 114)	1	2	U	1	1	U	1	2	U	8	3	17	1.25	.25	1.5	12	25
Dicyclopentadiene	U	2	1	U	1	U	U	2	U	6	5	21	1.25	.25	1.5	9	31
Diethylene Glycol	1	1	1	1	1	1	1	1	U	8	1	11	1.5	.25	1.75	14	19
Disopropanolamine	U	1	U	U	1	U	U	1	U	3	6	21	1.0	.25	1.25	4	26
Ethylphenol	U	1	U	U	1	U	U	2	U	4	6	22	1.0	.25	1.25	5	27
Glycerine (Glycerol)	1	1	1	1	1	1	1	1	U	8	1	11	1.5	.25	1.75	14	19
1 - Heptene (a - Heptylene)	2	U	U	1	U	1	1	U	U	5	5	20	1.5	.25	1.75	9	35
Isobutylene	U	2	U	U	1	U	U	2	U	5	6	23	1.5	.25	1.75	9	40
Isopentane	1	2	U	U	1	U	U	2	U	6	5	21	1.5	.25	1.75	10	37
Manganese Sulfate (Manganous Sulfate)	1	U	2	1	U	2	1	U	U	7	4	19	1.25	.5	1.75	12	33
Nonylphenol	U	1	U	U	1	3	U	1	U	6	5	21	1.25	.25	1.5	9	31
Oleic Acid	U	1	U	1	1	U	1	1	U	5	4	17	1.0	.25	1.25	6	21
Phthalic Anhydride	1	1	U	1	1	U	1	1	U	6	3	15	1.5	.25	1.75	10	26
Polypropylene Glycol Methyl Ether	U	U	U	U	U	U	U	U	U	0	9	27	1.5	.5	1.25		
Polyvinylchloride	U	2	U	U	1	U	U	1	U	4	6	22	1.5	.5	2.0	8	44
Potassium Phosphate	U	U	U	U	U	2	U	U	U	2	8	26	1.5	.5	2.0	4	52
Pyrenes	U	2	U	3	1	U	U	1	U	7	5	22	1.5	.25	1.75	12	38

Table IV-19
(Continued)

TITLE	AIR DISPOSAL			WATER DISPOSAL			LAND DISPOSAL			Total Known Effects Rating	Number of Unknowns	Maximum Potential Effects Rating	Production Rating	Distribution Rating	Total Production Distribution Rating	Final Known Hazards Rating	Maximum Potential Hazards Rating
	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects	Human Effects	Explosion Reaction	Ecological Effects								
Oxygen	1	2	1	1	1	1	2	2	1	12		12	1.5	.5	2.0	24	24
Silica	3	1	U	1	1	U	1	1	U	8	3	17	1.0	.25	1.25	10	21
Sodium Silicate	1	1	U	1	1	1	1	1	U	7	2	13	1.5	.25	1.75	12	23
Sorbitol	U	1	U	U	1	U	U	1	U	3	6	21	1.5	.25	1.75	5	37
Sulfur	1	1	1	1	1	1	1	1	U	8	1	11	1.5	.5	2.0	16	22
Tetrapropylene	1	1	U	1	1	1	1	1	U	7	2	13	1.5	.25	1.75	12	23
Thiocyanates	1	2	U	1	1	U	2	1	U	8	3	17	1.0	.25	1.25	10	21
Tripropylene (Nonene)	1	1	1	1	1	1	1	1	U	8	1	11	1.5	.25	1.75	14	19
Urea	1	1	U	1	1	1	1	1	U	7	2	13	1.5	.5	2.0	14	26
Zinc Chlorate	1	2	U	1	1	U	1	2	U	8	3	17	1.0	.25	1.25	10	21
Zinc Ethyl (Zinc Diethyl)	1	3	U	1	1	U	1	3	U	10	3	19	1.0	.25	1.25	12	24

Table IV-20
Specific Compounds Used as Warfare Agents by the Department of Defense

Below is a list of hazardous chemical compounds generally associated with DoD activities in development of warfare agents. Some of these compounds are also included among the list of hazardous compounds (Table IV-18, page IV-26), because they are also used in industrial processes which lead directly or indirectly to consumer products. Where appropriate (for the above reason), the ratings as developed have been included following the compounds named on the list below.

HD - Mustard
L - Lewisite
CG - Phosgene (30)
AC - Hydrocyanic Acid (50)*
NH - Nitrogen Mustard
CN - Tear Gas (26)
CS - Irritant Tear Gas
BM - Irritant Agent
WD - White Phosphorus (47)*
GB - Nonpersistent Nerve Gas
VX - Persistent Nerve Gas
Chloropicnic

Table IV-21
Hazardous Wastes Generated by Department of Defense Activities (Explosive Materials)

Acetylene (24)
Acetyl Peroxide
Amatol
Ammonium Nitrate (34)
Ammonium Perchlorate (44)
Ammonium Pirate (wet 36, dry 40)
Anfo
Aromatic Nitro Compounds, n. o. i.
Azides, n. o. i.
Benzol Peroxide
Black Power
Blasting Caps
Blasting Gelatin
Butyl Hydroperoxide
tert-Butyl Perbenzoate
Butyl Peroxypivalate
Cellulose Nitrate
Chloric Acid
1 Chloro-2, 4-Dinitrobenzene
1 Chloro-1-Nitropropane
Cumene Hydroperoxide
Cyclonite (RDX)
Cyclotol
Dibutyl Peroxide
1, 1-Dichloro-1-Nitroethane
Diisopropylperoxydicarbonate
2, 4-Dinitroaniline (40)
M-Dinitrobenzene
O-Dinitrobenzene (31)
P-Dinitrobenzene
2, 4-Dinitrophenol (36)
2, 4-Dinitrotoluene (40)
Double-base Propellants
Dynamite
Ethylene (25)
Ethylene Oxide (28)
Ethyl Nitrite

Table IV-21
(Continued)

Fulminates, n. o. i.
Guanidine Nitrate
Guanidine Perchlorate
Guncotton
HMX
Hydrazine (30)
Hydrogen Peroxide (42)
Lauroyl Peroxide
Mannitol Hexanitrate
Mercury Fulminate
Methyl Parathion (34)
Nitroethane (25)
Nitroguanidine
Nitromethane (26)
Nitroparaffin, n. o. i. (22)
1-Nitropropane (24)
2-Nitropropane (24)
Nitrostarch
p-Nitrotoluene (25)
Octol
Organic Nitrates, n. o. i.
Pentaerythritol Tetranitrate (PETN) (27)
Pentolite
Peracetic Acid
Perchloryl Fluoride (25)
Picric Acid (29)
Primacord
Propargyl Alcohol
Propargyl Bromide
Propyl Nitrate
Pyrotechnics (Flares, Fireworks)
Pyrooxilin (Nitrocellulose)
RDX (Cyclonite)
Safety Fuse
Smokeless Powder
Sporting Powder
Styphnates, n. o. i.
Tetryl
1, 3, 5-Trinitrobenzene
2, 4, 6-Trinitrotoluene

Table IV-22
Toxic Pollutants Involved in Conventional Munitions Production

1. Air Exposure

Acetic Acid (31) (5)
Acetic Anhydride (38) (6)
Ammonia (37) (4 + 1 unknown)
Butyl Alcohol
Cyclohexanone (26) (4)
Formic Acid (24) (7)
Iso-Butyl Acetate (21) (4)
Methylacetate (21) (4)
Methyl Ethylacetone
Nitric Acid (37) (7)
Oxides of Nitrogen
Toluene (36) (5)
Other Organics
SO_4

2. Water Exposure

Acetic Acid (31) (6)
Hexamine
Ammonia (37) (7)
Sodium Nitrate (30) (4)
Sodium Sulfate
Phenols (44) (7)
Iso-Butyl Acetate (21) (6)
Ammonium Nitrate (34) (4)
Nitric Acid (37) (8)
Oils
Explosives
Red Water (Stellite)
Sulfuric Acid (46) (8)

Table IV-23
Typical Department of Defense Waste Compounds and Materials

1. Maintenance Operations

   Cleaning Solvents
   Paints and Lacquers
   Plating Wastes
   Oily Wastes
   Surfactants

2. Supply Operations

   Toxic Munitions
   Explosive Munitions
   Propellants
   Oxidizing Agents
   Flammable Liquids
   Explosives
   Pyrotechnics
   Pesticides and Herbicides
   Drugs and Medicinals
   Corrosive Liquids
   Nuclear Weapon Components
   Laboratory Chemicals

3. Weapon Systems Support Operations

   Hydrazine (30)
   Monomethylhydrazine
   Borane
   Analines (35)
   Hydrocarbon Fuels
   Liquid Oxygen
   Solid Propellants
   Warheads—Nuclear, Non-Nuclear
   Fluorine (40)

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V. SURVEY AND INVENTORY OF TREATMENT AND DISPOSAL METHODS

1. INTRODUCTION

The analysis of treatment and disposal methods can be divided into four general categories of waste materials:

- Waterborne wastes
- Solid wastes
- Airborne wastes
- Thermal wastes.

Water is by far the largest disposal media. Municipal treatment systems and industrial treatment systems are based on the use of water to dilute, move, and process wastes. The treatment of wastes in water is the basis for much of the waste treatment methodology currently in use.

The collection, reduction, and disposition of solid wastes (and many liquid wastes) in landfills is a close second in the volume of waste handled. The garbage and trash collection processes typify this system of waste disposal.

The disposition of airborne wastes has received increasing attention recently. In past years, the disposition of airborne wastes was largely a process of releasing gases, fumes or particulates above the level of those immediately adjacent to the release site. Once airborne, such wastes were considered as adequately disposed.

Only in recent years has attention been given to the problems created by thermal wastes. The accelerating demands for power have focused attention on the hazards which result from massive releases of thermal energy.

When the tolerance level of man, other creatures, or vegetation is exceeded by one or more pollutants, a hazardous condition is created. If the tolerance level is not exceeded, the level of pollution is considered nonhazardous. The dependence of the definition of hazardous wastes on the tolerance threshold of the threatened specie makes it difficult to specify the pollutants and conditions which add up to a hazardous condition, i.e., a threat to health.

The insidiousness of health effects makes it difficult to establish the levels at which pollutants become acute threats to the various specie of the environment, and make it even more difficult to define the levels at which the chronic effects may be created.

The methods now used to dispose of unwanted materials (wastes) can be described, but the effectiveness with which they safely dispose of potentially hazardous materials is much more difficult to describe.

The paragraphs that follow describe the current practices which are used to dispose of unwanted materials, review the extent to which they are used, and make appraisals as to their probable effectiveness in reducing hazardous waste conditions.

2. CURRENT TREATMENT AND DISPOSAL PRACTICES

The discussion of these practices will cover the methods now in use to handle water wastes, solid wastes, air wastes, and thermal wastes.

The hazards that may result from improper disposal of waste materials vary widely. The effect of the release of highly toxic materials may range from an innocuous effect on the receiving air or water to an effect that endangers a substantial number of people. The toxicity, corrosiveness, explosiveness, etc., of the compound released are only some of the factors involved in establishing its effect. The others are the concentration developed and the presence of a susceptible population. If steps are taken to ensure that the amounts released do not exceed the threshold of any part of the susceptible population, however, no harm can result. The presence of a dangerous material is a warning that disposal methods must be capable of safely releasing such materials if no harm is to result.

While technical means exist to safely handle all dangerous materials, no controls exist to ensure that essential technical treatment steps are taken. At present, disposal controls do not provide a means to identify all potentially hazardous materials or the means to control their safe disposition. The technology currently in use may, in most cases, reduce the hazardous effects to the level of water and air pollutants. However, if the effects are chronic in nature, even those pollutants may in time produce broad-scale harmful effects on the susceptible population. The absence of an immediate acute effect on the exposed population is no assurance that chronic effects are absent.

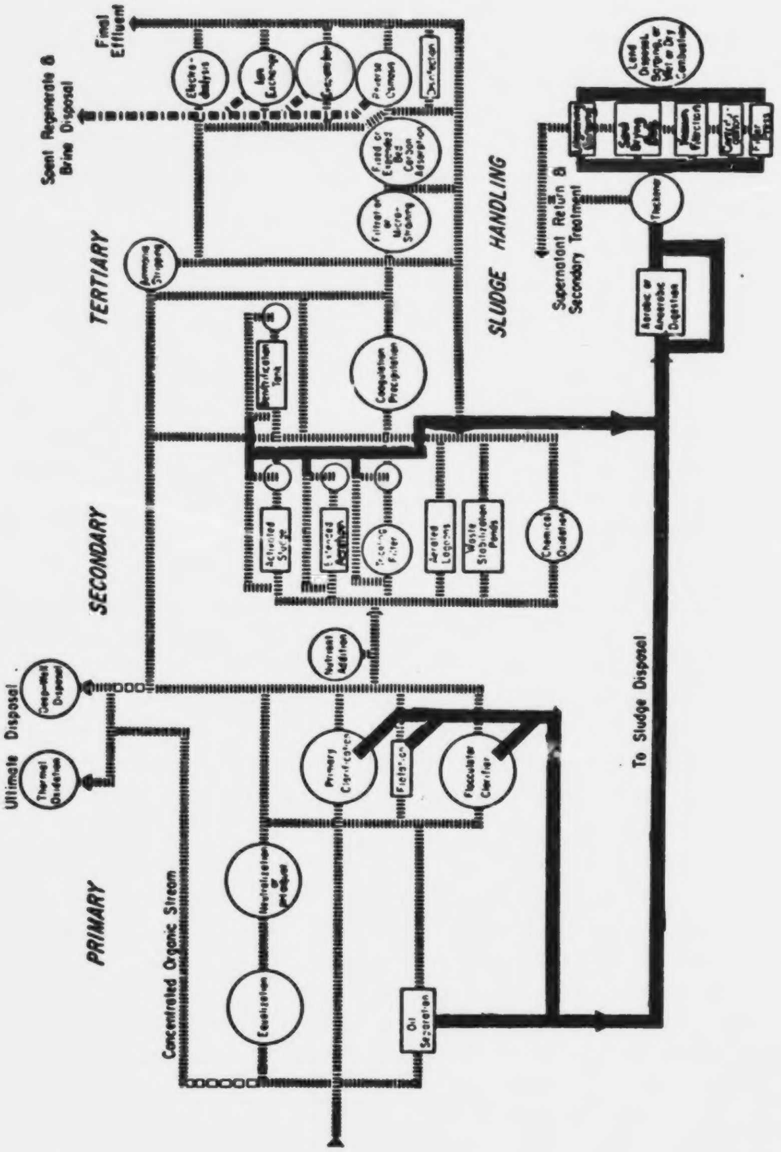
(1) Wastewater Treatment Methods

The wastewater treatment methods used in industry are comparable to municipal sewage treatment methods. The wastewater streams are processed to screen out, neutralize, or reduce contaminants contained in the stream. The treatment that can be provided is summarized in the chart (Figure V-1) on the following page.

In practice, the treatments shown are not widely applied, especially on a system basis that includes secondary and tertiary processes. Rather, they are treatments which are used in experimental or occasional applications, and should not be considered as typical system practices. If the full operation of potential treatments is applied, all contaminants can be removed and water can be restored to a drinkable state. The practical limiting factor is the costs which must be incurred to achieve full decontamination. Such costs are proportional to the volume of wastes to be treated, the level of contamination that must be removed, and the difficulties encountered in removing the particular contaminants.

The processes shown are based on the biological reduction of contaminants aided by chemical and physical treatments. Since many organic compounds are resistant to biodegradation, such waste streams should be isolated from other wastewater streams, when feasible, and separately treated or disposed of (i.e., thermal oxidation or deep-well disposal).

FIGURE V-1
Candidate Wastewater Treatment Processes—
Substitution and Sequence Diagram


Ultimate Disposal
Thermal Oxidation
Deep-Well Disposal
PRIMARY
SECONDARY
TERTIARY
Spent Regenerate & Brine Disposal
Final Effluent
Concentrated Organic Stream
Equalization
Neutralization or Proportional
Primary Clarification
Flotation
Flocculator Clarifier
Oil Separation
Nutrient Addition
Activated Sludge
Extended Aeration
Trickling Filter
Aerated Lagoons
Waste Stabilization Ponds
Chemical Oxidation
Denitrification Tank
Coagulation Precipitation
Ammonia Stripping
Filtration or Micro-Straining
Fixed or Expanded Bed Carbon Adsorption
Electro-dialysis
Ion Exchange
Evaporation
Reverse Osmosis
Disinfection
SLUDGE HANDLING
Supernatant Return & Secondary Treatment
To Sludge Disposal
Aerobic or Anaerobic Digestion
Thickener
Sand Drying Beds
Vacuum Filtration
Centrifugation
Filter Press
Land Disposal, Spraying, or Wet or Dry Combustion

Conceptually, waste treatment can be divided into three phases: primary, secondary, and tertiary.

In the primary phase, the waterborne constituents are separated from the water stream by simple actions such as:

- Screening
- Equalization, neutralization of pH adjustment
- Oil separation
- Flotation, flocculation or clarification.

These actions substantially increase the sedimentation of dissolved or particulate waterborne wastes.

Secondary treatments such as:

- Activated sludge
- Extended aeration
- Trickling filters
- Aerated lagoons
- Waste stabilization ponds
- Chemical oxidation

are used to biologically or chemically convert organic wastes to inactive sediments and water streams which are innocuous.

Tertiary treatment is applied to remove residual contaminants that are not affected by biological treatment. Such processes include:

- Ammonia stripping
- Coagulation and precipitation
- Filtration and microscreening

- Carbon adsorption
- Disinfection
- Electrodialysis
- Ion exchange
- Reverse osmosis
- Evaporation.

The latter four processes may be used to extract materials for later use or disposal. The final effluent from tertiary treatment is generally acceptable for return to the waters initially used to assist in the disposal process.

The sludges that are created as the water treatment proceeds can be handled in a variety of ways. As part of the water stream, they are subject to the same pretreatments applied to the water streams, i.e., pretreatments, thickening, and separations. Such treatments may include:

- Aerobic stabilization
- Anerobic digestion
- Lagooning
- Heat treatment

as well as dewatering by means of filter processes, or vacuum filters, centrifuges, or sand-drying beds.

Sludges may be transported by pipe, truck, rail or barge to land reclamation, landfill or ocean disposal sites or may be incinerated and the residual solids disposed of on landfills. Lime used in chemical treatment may be recalcified and reused, while carbon used in adsorption towers may be regenerated for reuse.

Carefully designed water treatment methods can remove most hazardous compounds from effluent streams. If treatment systems are not designed and operated properly, hazardous waste streams survive water treatment and pollute the receiving waters. In many cases, however, little or no treatment is given to industrial wastes.

(2) Air Pollution Controls

Thousands of different types of combustible organic compounds are released to the atmosphere from many different manufacturing operations. Examples include industrial dryers, ovens and furnaces used for the baking of paints and enamels; processes used in the manufacture of organic chemicals, inorganic chemicals, and paints and varnishes. Organic and inorganic materials released by refining processes, steel mill operations, nonferrous metal production, power production plants and automotive traffic also add to the pollution levels.

There is no simple way to overcome the pollution problems. Each manufacturing area has unique problems which may require differing treatment methods. Unlike water treatment methods, there is no basic set of treatments whose sound application can ensure clean air.

Because of the wide variety of toxic compounds which may be emitted, each control system must consider the explosive and fire hazard effects which are related to the gases and particulates in each set of emissions, and adapt available technology to adequately deal with the total effects that are to be controlled.

The status of current technology in the control of emissions to the atmosphere was presented in hearings before the Subcommittee on Air and Water Pollution of the Committee on Public Works, March 15-18, 1967, and is contained in Table V-1, which is presented on the following pages.

As Table V-1 indicates, adequate control technology generally existed even in 1967, but the need for its application has not been fully accepted by industry and the means to enforce its use have not been available to all enforcement authorities. The particular technology applications best suited to pollution control are heavily dependent on the technology and economics of the process to be controlled. Recently built plants and new

Table V-1
Status of Current Technology in the Control of Emissions to the Atmosphere*

	Particulates		Sulfur oxides		Carbon monoxide		Others		
Source	C	NC	C	NC	C	NC	C	NC	Remarks
Domestic and commercial heating plants:									
Coal fires (not hand fired)		(*)	X			X	Smoke	NO_x	CO not of major concern.
Oil fired		(*)	X			X	Smoke	NO_x	Control of SO_x only by switching to low sulfur fuel.
Gas fired					X			NO_x	Control of CO by good combustion.
Industrial heating plants:									
Coal fired	X			X	X		Smoke	NO_x	Control of particulate during soot blowing needed.
Oil fired		(*)		X	X		Smoke	NO_x	Partial control of NO_x is possible.
Gas fired					X			NO_x	Partial control of NO_x is possible.
Electric generating plants:									
Coal fired	X			X	X		Smoke	NO_x	Control of particulate during soot blowing needed.
Oil fired	X			X	X		Smoke	NO_x	Partial control of NO_x is possible.
Gas fired					X			NO_x	Partial control of NO_x is possible.
Hand-fired coal burning furnaces	X				X		Smoke	NO_x	Controlled by elimination of hand firing of coal which may be a hardship on low-income households.
Incinerators:									
Domestic; commercial; industrial:									
Single chamber		X				X		Smoke; organics	Can be controlled by eliminating single-chamber incinerators.
Multiple chamber	X				X		Smoke; organics		More effective control of particulate emissions is needed.
Municipal	X				X		Smoke; organics		
Auto body and scrap wire	X				X		Smoke; organics		
Mineral industry:									
Cement	X							NO_x	Particulate control difficult for old plant.
Insulation	X							NO_x; odors uncontrolled in some glass wool plants	
Glass manufacturing	X						Fluorides	NO_x	Can control fluoride and visible emissions by raw material control.
Frit	X							NO_x	
Phosphate fertilizer	X						Fluorides; ammonia		Fluoride control difficult on older plants and certain processes.
Asphalt concrete batching	X							Odors; NO_x	Fugitive dust control difficult at older plants.
Concrete batching	X								
Carbon black:									
Furnace black	X							NO_x	SO_x may be a problem and cannot be controlled.
Channel black		X						NO_x	
Coal cleaning	X								Older plants often difficult to control.
Charcoal manufacturing	(*)							Organics; smoke	
Ceramics	X							Fluorides; NO_x	Fluorides from decomposition of certain clays.
Refractories	X							NO_x; fluorides, if in raw material	
Rock and gravel processing	X								Fugitive dust difficult to control.
Metallurgical industry:									
Iron and steel:									
Coke plants:									
Slot type		X		X			NH_3, benzol, toluol, organics	Odors	Emissions from charging and discharging ovens. Old plants are very difficult to control.
Beehive		X		X				Organics; odors	Completely noncontrolled.
Blast furnace	X				X			NO_x	CO used as fuel.
Sintering plants	X			X			Fluorides	NO_x	Control difficult on older plants.
Open hearths	X						Fluorides	NO_x	Being phased out.
Oxygen lance open hearths	X							NO_x	
Basic oxygen	X				X			NO_x	Replacing basic open hearth.
Electric furnaces	X							NO_x	Emissions not controlled during tilting and charging.
Scarfing	(*)							NO_x	
Grey iron cupola:									
Production	X				X		Organics	NO_x	
Jobbing	(*)				X		Organics	NO_x	
Ferroalloys	X							NO_x	
Aluminum:									
Reduction	X						Fluorides	Carbonaceous matter	Fluoride control poor in Soderberg furnaces.
Secondary operations	X						Chlorine		
Smelting:									
Lead ores	X		X					NO_x	
Zinc ores	X		X					NO_x	
Copper ores	X		X					NO_x	

NOTE: See footnotes at end of table, p. 354.

KEY: C—Control technology generally available; NC—Control technology not generally available; CO—Carbon monoxide; HC—Hydrocarbons; SO_x—Sulfur oxides; NO_x—Nitrogen oxides.

Table V-1
(Continued)

Source	Particulates		Sulfur oxides		Carbon monoxide		Others		Remarks
	C	NC	C	NC	C	NC	C	NC	
Refining:									
Zinc	X							NO_x	Particulate control at small scrap reclaiming operations is economically burdensome.
Brass	X							NO_x	
Taconite plants	X							NO_x	
Petroleum industry:									
Petroleum refining:									
Separation (crude distillation, etc.)							HC, H_2S		
Conversion:									
Catalytic cracking	X				X		H_2S	NO_x	
Reforming							H_2S		
Treating							Odors		Odors often noticeable.
Blending							HC		
Petroleum production							HC		
Petroleum marketing:									
Bulk plants							HC		
Service stations								HC	Partial control possible.
Solvent evaporation:									
Drycleaning							Solvents		Recovered.
Paint spraying	X							Solvents(*)	Generally uncontrolled.
Industrial storage								Solvents(*)	Breathing losses usually uncontrolled.
Degreasing							Solvents		
Bake oven							Solvents	NO_x	
								Water vapor	Water vapor controlled in Europe. Some odors detectable at < 1 ppb.
Kraft pulpmills:									
Digesters							Sulfur compounds		
Smelt tank	X						Sulfur compounds		
Lime kiln	X						Sulfur compounds	NO_x	
Recovery furnace	X			X	X			Sulfur compounds; NO_x	Control of odorous sulfur compounds usually not satisfactory.
Evaporators								Sulfur compounds and odors.	
Oxidation towers							Sulfides, odors		
Chemical industry:									
Sulfuric acid			X				Sulfuric acid mist	NO_x (chamber process)	Better control of SO_2 desirable.
Nitric acid							NO_x		
Hydrochloric acid							HCl, solvents		
Phosphoric acid							Fluorides; phosphoric acid mist.		Flouride control often difficult. Particulate control difficult for submerged combustion acid evaporation.
Hydrofluoric acid							HF		
Chlorine							Cl_2		Cl_2 leaks are hard to control at old plants.
Ammonia (synthetic)							NH_3 organic bases		Well-developed technology and mammoth plants.
Lime	X							NO_x	
Soda ash:									
Ammonia soda	X						NH_3		
Trona	X								
Caustic soda:									
Lime-soda									Practically obsolete (see chlorine plants).
Electrolytic	X						Cl_2		Odor from Cl_2 distillation tower bottoms if exposed.
Polyethylene							HC		Tight process system.
Polyvinyl chloride							HCl, vinyl chloride, vinylidene chloride, vinyl acetate.		Tight process system.
Alum	X						Mists		Old plant controls may be poor.
Paint and varnish	X						Odors, solvents	NO_x	Old plant controls difficult. Often have odors.
Synthetic rubber							HC, solvents, odors		Odor control only fair.
Rubber tire manufacturing	X							Odors	
Oil bodying operation	X						Odors		
Formaldehyde					X		Methanol, formaldehyde, HC.		Tight system.
Methanol (synthetic)					X				Tight system.
Phenol (synthetic)							Benzene, toluene, odors		
Rayon							Sulfides, carbon disulfide odors.		Odor control only fair.

NOTE: See footnotes at end of table, p. 354.

KEY: C—Control technology generally available; NC—Control technology not generally available; CO—Carbon monoxide; HC—Hydrocarbons; SO_x—Sulfur oxides; NO_x—Nitrogen oxides.

Table V-1
(Continued)

Source	Particulates		Sulfur oxides		Carbon monoxide		Others		Remarks
	C	NC	C	NC	C	NC	C	NC	
Insecticides:									
Chlorinated	X						Cl_2; HCl	Odors	
Phosphorus type	X							Odors	Some are supertoxic.
Carbamates	X								Some are highly toxic. Nonpersistent.
Soap and detergent	X							Odors	Partial control of odor possible.
Phosgene							Cl_2 and phosgene		Highly toxic. Tight system, mainly captive use.
Phthalic anhydride	X						Odors		
Food processing and agriculture:									
Cotton ginning	X							Pesticides	Some gins have cost problems. Incineration of cotton trash of concern in regard to arsenic.
Alfalfa dehydrating	X							Odors: NO_x	Often unsatisfactory.
Feed and grain mills	X								
Flour mills	X								
Meat smoking	X						Odors; smoke		
Starch manufacturing	X								
Fish processing								Odors	Cl_2 scrubbers. Partial control of odors possible.
Coffee roasting	X						Odors	NO_x	Fume burners.
Rendering							Odors		Complete odor control difficult.
Agricultural burning:									
Fields		X						Organics, odors	
Forests		X						Organics, odors	
Crop spraying							Drift	Many insecticides and herbicides.	Hazardous to life unless carefully done.

[a] Reference (6), pp. 2274–2277 (J. H. Ludwig).

[b] Emission control is possible but cost is unacceptably great compared to capital investment of plant or as a factor in cost of finished products or in relationship to the ability of persons responsible for control to bear the costs.

NOTE.—Nitrogen oxides (NO_x) are always formed in high-temperature combustion. Amounts vary with conditions. Feasible means for adequate control of emissions are not available.

KEY: C—Control technology generally available; NC—Control technology not generally available; CO—Carbon monoxide; HC—Hydrocarbons; SO_x—Sulfur oxides; NO_x—Nitrogen oxides.

processes generally incorporate effective pollution reduction measures. However, the costs of retro-fitting existing processes may make it uneconomic to continue the current production methods. The degrees of control that are acceptable to local authorities will influence heavily the techniques that are adopted. In some cases, the control technology which has been developed is inadequate to the control needs.

(3) Solid Waste Disposition

As the methods used to control wastewater and air pollution find increased application and improvement, the disposal of solid wastes from industrial operations will become a greater problem. Wastes extracted from the water and air will become part of the solid waste disposal process. Figure V-2 illustrates how solid industrial wastes arise and the typical treatments involved in their processing as industrial plant wastes.

The processing of industrial solid wastes will become a larger task as the water and air standards are tightened. Should pollution standards be established to control leaching from existing sludge piles and lagoons, for example, an enormous effort will be required to process such accumulations and remove or contain those compounds polluting ground and runoff waters. If concern extends to the mineral industry solid wastes, such as mine and mineral processing wastes, solid waste processing and disposal will become the largest of all waste management efforts.

To illustrate the potential magnitude of this problem, Tables V-2 and V-3 present sources and magnitudes of solid wastes generated by the minerals and fossil fuel industries, and the pollutants that result from mining operations are summarized in the following paragraphs.

- Physical Pollutants—Solid particulate material, either mineral or organic, which enters a stream or pond may react chemically with water or other substances to form even more harmful compounds. An estimated total of 2,000 abandoned mine and mill waste dumps are contributing to water pollution. Stabilization of these dumps by planting vegetation

FIGURE V-2
Solids Handling, Treatment and Disposal

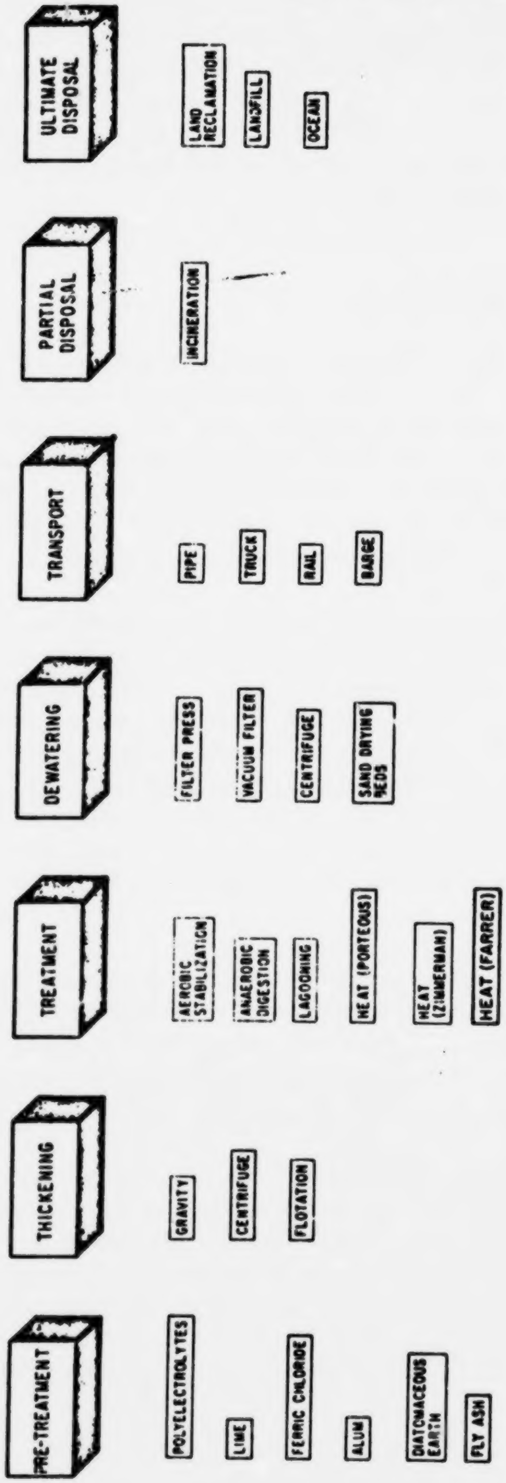

PRE-TREATMENT
POLYELECTROLYTES
LIME
FERRIC CHLORIDE
ALUM
DIATOMACEOUS EARTH
FLY ASH
THICKENING
GRAVITY
CENTRIFUGE
FLOTATION
TREATMENT
AEROBIC STABILIZATION
ANAEROBIC DIGESTION
LAGOONING
HEAT (PORTEOUS)
HEAT (ZIMMERMAN)
HEAT (FARRER)
DEWATERING
FILTER PRESS
VACUUM FILTER
CENTRIFUGE
SAND DRYING BEDS
TRANSPORT
PIPE
TRUCK
RAIL
BARGE
PARTIAL DISPOSAL
INCINERATION
ULTIMATE DISPOSAL
LAND RECLAMATION
LANDFILL
OCEAN

Table V-2

Solid Wastes by Type Generated by the Minerals and Fossil Fuel Industries in 1968

(1,000 Short Tons)

Industry	Mine Waste*	Mill Tailings	Washing Plant Rejects	Slag	Processing Plant Wastes	Total
Copper	492,634	172,751	-------	4,298	-------	669,683
Iron and Steel	157,518	135,798	-------	16,133	1,315	310,764
Phosphate Rock	282,184	-------	110,078	4,543	14,895	411,700
Lead-Zinc	3,504	18,577	-------	165	-------	22,246
Alumina	2,340	682	-------	-------	4,954	7,976
Coal:						
Bituminous	-------	-------	97,107	-------	-------	97,107
Anthracite	-------	-------	-------	-------	-------	-------
Coal Ash	-------	-------	-------	-------	29,735	29,735
Other	144,003	90,535	NA	NA	NA	234,538
TOTAL	1,082,133	418,343	207,185	25,139	50,899	1,783,749

*Includes overburden moved during surface mining activities and waste removed from underground mines, excludes overburden displaced by surface coal mining operations.

NA = Not Available.

Table V-3
Solid Wastes Generated by the Mineral and Fossil Fuel Mining and Processing Industries in 1968 and Accumulated Up to 1968 (1,000 Short Tons)

Industry	1968	Accumulated up to 1968
Copper	669,683	9,078,544
Iron and Steel	310,764	4,687,858
Phosphate Rock	411,700	1,945,144
Lead-Zinc	22,246	492,525
Alumina	7,976	61,521
Bituminous Coal	97,107	1,849,145
Anthracite Coal	------	910,000
Coal Ash	29,735	455,773
Other	234,538	4,576,281
Total	1,783,749	24,055,791

is hindered by the high acidity of alkalinity of the material. Studies indicate that sediment yield from strip mines in 1,000 times that derived from forested areas, and that half of the 1.2 million gallons of waste processing water is released untreated to adjacent streams. This sediment may also include valuable mineral resources.

- Chemical Pollutants—Acids, alkaline solutions, mineral salts drained from mines, and waste heaps accrued from the minimg and processing of mineral sulfide ores are examples of a type of pollutant that is more difficult to treat than other solids.

The mineral sulfides treat chemically with air and water to form sulfuric acid, which reacts with other minerals to cause other ions, such as aluminum, manganese, lead, zinc and arsenic. These enter water by draining from spoil material or by ground water percolation through spoil material on its way to nearby streams. When the concentration of these pollutants is sufficiently great, "dead water" which is toxic to living organisms results.

Another effect of acid drainage from these wastes is the formation called "yellow boy," a rust-colored precipitate of ferric hydroxide that accumulates in stream beds. Due to its coating action it smothers aquatic life (coast gil structures), and may seal stream bottoms to the extent that water can no longer percolate through the bed to oxygenate the breeding areas for aquatic species.

Physical and Chemical Pollutants—Compounds used in cleaning, milling and beneficiation processes for the recovery of mineral values may be inadvertently lost, and reach streams by spills, direct flushing, or from overflows of natural leaching of tailing ponds. Normally they are impounded in the settling areas, but seepage through or breaks in the dam permit these compounds to contaminate ground waters and streams. Most of these effluents are foul smelling and discolor the water. In some instances they are toxic. Phosphates in water may stimulate abnormal growth of algae and other aquatic flora which consume oxygen and thereby sufficate other forms of stream life.

> Physical and chemical pollutants from mining have adversely affected 18,000 miles of streams in the United States. Mine sources contribute large volumes of sediment, and more than 4 million tons of sulfuric acid, to the streams. Surface mining alone has adversely affected 8,700 miles of streams. Underground mining is responsible for degrading approximately 9,300 miles of stream and 22,000 acres of lakes and other water bodies in 31 states (Appendix A-1, Table A-1-5).

(4) Thermal Pollution

As demand grows for energy, greater recognition must be given to the effects of increased use of energy. Thermal pollution is an unwanted by-product of power generation. The debate as to the virtues of fossil fuels in comparison to nuclear fuels centers around the issue of thermal pollution. Disposal of the heat contained in discharges from powerplants without adverse effect in the environment is one of the problems of all steam-electric plants, nuclear as well as fossil fueled. Because of its relatively low steam temperature (500°F versus 1,000°F), a water-cooled nuclear plant achieves a thermal efficiency of only 32.5 percent compared with over 40 percent for a fossil-fuel plant. Until the more advanced fast-breeder reactors are in use, the use of nuclear powerplants will tend to increase thermal pollution. Unless the rate of increase of power demand can be slowed, new power sources will rapidly increase the thermal load on the water streams of our nation.

3. WASTE STREAMS, HAZARDOUS WASTES, AND DISPOSAL METHODS

There are a variety of substances that can create hazardous conditions. The hazardous condition is the result of a dangerous property of a compound or a group of compounds. The extent of the danger is dependent upon the amounts of the dangerous compound present, its dilution by inert substances, and the proximity of persons or things that may be harmed by the condition created by the compound.

Hazardous conditions may be created by compounds that are

- Radioactive
- Explosive
- Corrosive
- Toxic
- Flammable
- Pathogenic
- Carcinogenic
- Mutagenic

or have other more exotic long-range effects when their tolerance levels are exceeded.

The safe handling of such compounds is dependent on the degree of control that can be exercised to (1) isolate the susceptible population, (2) remove the condition that triggers the danger (fire-explosion), or (3) attenuate the effect below the threshold of susceptibility.

Waste treatment and disposal techniques use all of these approaches. Historically, the approach has been to attenuate the effects (through simple dilution) below the level that makes the effects unacceptable. Tolerance on the part of the public for polluted air and water made this technique effective. As air and water standards become more stringent, simple attenuation of effects will be less acceptable as a disposal method.

The identification of hazardous waste streams is not simple: the existence of a dangerous substance must be shown; the concentration of this substance above the level of normal susceptibility must be provable; and actual damage to a susceptible population must have occurred. In the absence of these proofs, the violation of a specific standard must be shown.

The variety of waste streams with potential hazardous effects is nearly infinite. The producers of a single product may use materials or processes that may create hazardous conditions when their product and/or process wastes are added to those of others. If the variety of products and processes increases, the probability of creating hazardous waste effects is likely to increase. If the production process is close to population centers, the acceptance of hazardous effects is likely to decrease.

In the presentation that follows, the typical waste streams of various industries are reviewed. The typical treatment given these waste streams are noted, and an evaluation made of the sufficiency of such treatments to render such waste streams nonhazardous. Since there is a wide variation in the treatment that can be given within an industry, it is not possible to do more than rate the general level of treatment that typifies the industry. Only a plant-by-plant evaluation that has the full cooperation and technical participation of the operators can establish the actual hazards that exist in all waste streams.

The following industries have been analyzed and their practices in treating wastes evaluated.

SIC	INDUSTRY
20	Food
22	Textiles
26	Paper and Allied Products
28	Chemicals
2812	Alkali and Chlorine
2815	Cyclic Intermediates
2818	Organic Chemicals
2819	Inorganic Chemicals
282	Plastic Materials and Synthetics
283	Drugs
284	Soaps and Cleaners
285	Paints

SIC	INDUSTRY
287	Agricultural Chemicals
289	Explosives
291	Petroleum Refining
311	Leather
329	Asbestos
331	Blast Furnaces and Basic Steel
333	Primary Nonferrous
347	Plating and Polishing

The following tables illustrate typical waste streams that occur in each industry and the treatment procedures that are used. Some industries are relatively homogeneous in processes and products (e. g., the textile industry), while others such as the chemical industry are quite diverse as to products made and processes used. In the latter type industries, the wastes shown are examples only. The particular wastes and treatment accorded these wastes are unique to each production facility, and specific identifications will demand a research effort far beyond the scope of this study.

Table V-4
Food Industry - SIC 20
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER										
. Meat	Slaughtering	Screening	Sedimentation Aeration	Lagoons	None	No	600-3500 gal/1000#prod BOD 2-28#/1000# prod TS 3-56#/1000# prod	Water Pollutant	10%	65%
	Rendering	Grinding	Cooking Separation	By-products	None	No				
. Dairy	Process Waste	Grit Removal	Aeration Trickling Filters	Lagoons Irrigation	None	No	10-16 pop. equiv./1000# milk	Water Pollutant	4	10
. Canning	Process Waste	Screening	Sedimentation Aeration	Lagoons	None	No	50 gal/case of food	Water Pollutant High or Low pH	6	35
. Grain Mill	Modified Starch Wastes	By-product Recovery	Municipal Sewage Activated Sludge	Lagoons	Acid Residues	No	5 pop. equiv./bushel (corn) 150 pop. equiv./ton (potatoes)	Water Pollutant	5	30
. Sugar	Process Wastes	Screening	Sedimentation Aeration	Lagoons	Alkaline Residues From Beets	No	7# BOD/ton	Water Pollutant	8	2
. Fermentation	Still Wastes	By-product Recovery	Sedimentation Aeration	Lagoons	None	No	3 pop. equiv./bushel . 50#BOD/bushel	Water Pollutant	3	52

Table V-4
(Continued)

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
AIR										
. Canning	H_2S Mercaptans	None	None	Air	None	None	--	Air Pollutant	Unknown	NA
. Grain Mill	Volatiles	--	Steam Stripping	Air	Air Pollutants	None	--	Air Pollutant	Unknown	NA
. Fermentation	Volatiles	--	Stripping	Air	Air Pollutants	None	--	Air Pollutant	Unknown	NA
SOLID										
. Meat	Sludges	--	Activated Sludge Lagoons	Land Compost Fertilizer Irrigation	None	Liquid Sludge		None	Unknown	No
. Canning	Trimmings	--	Fine Screening Comminuting	Land Fill Animal Feed Ocean Dumping	None	Sludges	.1-.7 tons/raw ton	None	Unknown	No
. Grain Mill	Steepwater Fiber Solids	By-product Recovery	Lagoons	Land	None	Sludges	--	None	Unknown	No

Table V-5
Textile Mill Products - SIC-22
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER										
	Wool Scouring	Solvent Recovery Degreasing	Primary Treatment Sedimentation Lagooning	Water Lagoons Sand Bed	(1)	No Yes	50-60# chemicals 1000# grease, suint and dirt/1000# clean wool	Water Pollutant	2-24%	38%
	Cotton Desizing, Scouring, and Dyeing	--	Equalization and Holding Activated Sludge	Water Lagoons	(1)	No	720# starch, surfactants chemicals/ 1000# cotton	Water Pollutant	13-14%	22%
	Synthetic Textile Wastes	Screening	Sedimentation Lagooning	Water Lagoons	(1)	No	300#/1000# syn (Avg.	Water Pollutant	30-40%	40%
AIR										
	Carbonized Wool	--	Cyclone Collectors	Air	(2)	No	Unknown	Water Pollutant		
	SO_x	--	Wet Scrubbing	Air		No	Unknown	Water Pollutant	No	No
	Organic Solvents	--	Redistilling	Air	(2)	No	Unknown	Air Pollutant		
	Lint and Dust	--	Filters	Air		Yes	5-8#/100# cotton			

(1) Toxic Residue may include: Acids and Alkalis, Oxidizers, Flammable Solvents, Toxic Metal Salts, Dyes, and Phenols.

(2) Toxic Residue may include: NO_x, H_2S, and Mercaptans.

Table V-6
Paper and Allied Products - SIC-26
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER										
	Preparation Wastes	Screening	Filtration Settling	Water	None	No	20-180#/ton pulp	Water Pollutant	9-38%	<1%
	Chemical Pulping Wastes	Neutralization	Irrigation Flocculation Sedimentation Holding Ponds	Water	Sulfates Organics Soaps	No	--	Water Pollutant	9-38%	<1%
	Sulfite Waste Liquor	--	None	Water	Sulfites Lime Organics	No	200-300 # sulfur 150-200 # lime	Water Pollutant	9-38%	<1%
AIR										
	Black Liquor	Degasing	Evaporation Scrubbing Combustion Recycle of Chemicals	Air	SO_2 Mercaptans H_2S Organic Compounds (i.e. Tall Oil)	Recycled Chemicals	500# lime/ton 250# Na OH/ton	Air Pollutant		
	Blow & Flue Gases	De-Entrainer	Dilution Burning Scrubbers Precipitators	Air	SO_2 Mercaptans Methyl/ Sulfide H_2S Fly Ash	None	--	Air Pollutant		
	Red Liquor		Evaporators Burning Recovery MgO and SO_2	Air	SO_2	None	--	Air Pollutant		
SOLIDS										
	Sludges		Dewatering Land Fill	Land	None	None	--	--		

Table V-7
Petroleum Refining and Related Industries - SIC-29
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical [1] Pre-Treatment	General Treatment [2]	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors [3]	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER										
	Sour Water	Steam Stripping Solvent Extraction	Chemical:		Water Pollutants	No	6-7 gallons/gallon of product	Water Pollutant		
	Spent Acids	Neutralization Recycling	-Coagulation -Precipitation -Oxidation							
	Spent Caustics	Neutralization	Biological	Water Effluent and Sludge Landfill	Sludge Pollutants	Yes	1-2#/barrel of crude	Water Pollutant	100,000	<1
	Slop Oil	Oil Separators	-Activated Sludge -Aerated Lagoons -Trickling Filters							
AIR										
	Fly Ash	Scrubbers		Landfill		Yes	.8#/bal. of fuel oil[4]			
	Hydrocarbons	Filters					.1-.6% crude through-pit	--		
	NO_x	Incineration	Collect and Landfill Filtercakes and Other Solids		Filtercakes or Collection Solids		5-65#/1000 bal feed			
	Aldehydes						12-19#/1000 BBL feed			
	Ammonia						5-54#/1000 BBL feed			
SOLIDS										
	Boiler Blow-down	None	None	Landfill	Inorganic Metallic Salts	No	No Data			
	Spent Catalysts Catalysts	Recycled						Toxic Metallic Salts		
	Trash									

[1] Tables A-6-3, A-6-4, A-6-55

[2] Appendix A-6-19 to A-6-78

[3] Tables VI-1, 3, and 4

[4] Air Pollution Steam pg. 117-118

Table V-7
(Continued)

Waste Media	Type Waste	Typical Pre-Treatment[1]	General Treatment[2]	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors [3]	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
PROCESS	Off Spec Products	None	Recycle	Deepwell	Concentrated Toxic Wastes	Yes	Typical Deepwell 35-650 gallons/ min.	Acutely Toxic Chemicals		
	Toxic Wastes		Segregate	Sludge						
	Oily Wastes		Incinerate							
PRODUCT	Gasoline	None	Industrial Disposal Processes for Cyclic Chemicals	Water or Landfill	Residual Toxic Compounds	Yes	Note 1	Water Pollutants		
	Lube Oils									
	Cyclic Intermediates									
	Commercial Chemicals		Municipal Sewage and Landfill for Household and Commercial Chemicals	Water or Landfill	Containers with Toxic Residues	Yes	Note 1	Acutely Toxic Flammable Explosive		
	Household Chemicals									

[1] Tables A-6-3, A-6-4, A-6-55

[2] Appendix A-6-19 to A-6-78

[3] Tables VI-1, 3, and 4

[4] Air Pollution Steam pg. 117-118

Note 1: The amounts of such product wastes are estimated as 1-2% of the total production of organic chemicals resulting from conversion of 302,000,000 barrels of oil to chemical products.

Table V-8
Leather Industry - SIC-31
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment[1]	General Treatment[2]	Disposal Media	Toxic Residue	Collectable Residue	General Quantification[3] Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER										
	Beam House -Alkalis -Sulfides -Limes -Brine	Screening	Sedimentation Holding Lagoons							
	Tan House -Chrome Salts -Tanning -Acids -Organics	None	Note: Neutralization Coagulation Activated Sludge Aeration are used by less than 10% of industry	Water Effluent and Sludge Landfill (±30%) Municipal Sewage (±70%)	Chrome Salts Dyes Oils	None	15.6 billion gallons effluent/yr 3-4% sludge (600 million gallons)	Water Pollutant	Primary 20% Secondary 10%	67%
	Retan & Finish -Chromes -Dyes -Oils	None	±30% Not Treated							
SOLID										
	Hair, Fleshings, Trimmings, Dirt, Manure	Screening Sale as Rital Materials	Sedimentation	Landfill	None	None	Estimated as 5% of the 1.7×10^7 lbs hide processed annually	None		
AIR										
	Hydrogen S Sulfide Acids Particulates Solvents	Solvent Recovery	None	Air	Air Pollutants	None	No Data	Air Pollutant	Unknown	NA

[1] Tables A-7-1, 2, and 3

[2] Tables A-3-4 and 5

[3] Pages A-7-2 and 3, A-7-23 and 24

Table V-8
(Continued)

Waste Media	Type Waste	Typical Pre-Treatment[1]	General Treatment[2]	Disposal Media	Toxic Residue	Collectable Residues	General Quantification Factors[3]	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
PROCESS										
	Off Spec Product	Recycled When Feasible					No Data	None		
	Raw Materials Less: -Acids -Alkalis -Dyes -Chromic Salts		Treated With Other Wastes	Water Effluent	Water Pollutants	None			Unknown	NA
PRODUCT										
	Trimmings	None	Sale	None	None	None	--	None	--	--

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[1] Tables A-7-1, 2, and 3

[2] Tables A-7-4 and 5

[3] Pages A-7-2 and 3, A-7-23 and 24

Table V-9
Stone, Clay, Glass and Concrete (Asbestos Products) - SIC-32
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment[1]	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER	Asbestos Insulation	--	Sedimentation Neutralization	Water or Landfill	No	No	.2-2.0# per ton of product	Landfill Dusts	Primary 38% Secondary 28%	15%
	Asbestos Paper	--	Sedimentation Neutralization	Water or Landfill	No	No		Landfill Dusts		
	Asbestos Cement	--	Sedimentation Neutralization	Water or Landfill	No	No		Landfill Dusts		
AIR	Mining and Milling Fibers	--	Filters Cyclone Separators	Landfill or Air	Asbestos Dust Asbestos Dust	Yes No	93# per ton of asbestos	Asbestos Dust	Unknown	NA
	Textile Wastes	--	Filters Cyclone Separators	Air	Asbestos Dust	No	Unknown	Asbestos Dust	Unknown	NA
	Landfill	--	None	Land	Asbestos Dust	No	Unknown	Asbestos Dust	None	NA
SOLID	Milling and Mining Slag	--	None	Landfill	Asbestos Dust	No	Unknown	Asbestos Dust	Unknown	NA
PRODUCT	Asbestos Textiles Insulation Brake Lining	--	--	Air	Asbestos Dust	No	Unknown	Asbestos Dust	NA	NA

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[1] Table A-8-3

Table V-10
Medical and Other Health Services - SIC-80
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard
WATER								
	Radioactive Wastes	Storage	Decay	Sewage Contract	None	Yes	< 1000#/year/hosp.	Short Life Low Activity Water Wastes
	Body Wastes	--	Sewage	Water	None	No		
	Body Wastes (Contamination)	Sterilization	Sewage	Water	None	Yes		None
AIR								
	Tissue and Pathogenic Wastes	--	Local Incineration	Air	Unburned Residuals	Yes	Unknown	Air Pollutant
SOLIDS								
	Radioisotopes	Storage	None	Contractor	Long Half-Life Radiation	Yes	<50#/year/hosp	Radioactive
	Pathological	Autoclaving	Incineration	Land-Air	None	Yes	1-2#/bed/week	Infection
	Drugs	Storage	Incineration Burial	Air Land	None Unknown	Yes Yes	< 1#/bed/week	Misuse
	Disposable Medical Supplies	Storage	Incineration Compaction and Burial	Air Land	Acid Fumes None	Yes	1-2#/bed/week	Air Pollutant
	General Rubbish	Storage	Trash Collection	Air-Land	None	Yes	>5#/bed/day	--

Table V-11
Plastic Materials, Synthetic Fibers, Rubber, Resins - SIC-282
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER	Cellulosics	Settling Lagoons	Activated Sludge	Water	Zn Salts Trace Mg-Cu	No	overall 20#/1000# prod.	Toxic Metals	Primary 68% Secondary 40%	<1%
	Polyethylene	Separation	None	Water	Trace Catalysts	No	--	Toxic Metals	--	--
	Plastic Material & Resins	Settling Lagoons Carbon Adsorption Ion Exchange	Activated Sludge	Water	Brine Trace Metals Phenols	No	18-30#/1000# prod.	Toxic Metals	Primary 80% Secondary 27%	8
	Organic Fibers	Settling Lagoons	Activated Sludge Aeration	Water	Acid Wastes	Yes[1]	18-35#/1000# prod.	Toxic Metals	14: 100	<1
AIR	Incinerator Wastes	--	Incineration	Air	SO_x NO_x HCl	No	--			
SOLID	Process Wastes	-- --	Landfill	Land	None	Yes	.5% of prod.	None		

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[1] Deep-Well Disposal is used for acid wastes and non-biodegradable wastes.

Table V-12
Drug Industry - SIC-283
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors [1]	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER										
	Fermenter Wastes "Spent Beer"	Screening Neutralization	Trickling Filters	Water	None	No	--	None	Primary 37% Secondary 12%	14%
			Activated Sludge	Land	None					
			Spray Irrigation	Land	None					
			Municipal Sewage	Water	None					
	Chemical Solvents	Solvent Extraction	Incineration	Air	None	No	Unknown	None	None	None
			Collected by Disposal Contractor	--	Toxic Solvents	Yes	Unknown	Toxic Solvents		
	Chemical Wastes	Neutralization	Municipal Sewer	Water	None	No	--	None	Primary 37% Secondary 12%	14
			Deep Well	Land						
			Activated Sludge	Land						
			Lagoons	Water						
	Radiological Wastes	Collection	Decay in Storage	Water	Yes	Yes	Unknown	Radiation	Yes	Yes
AIR	Dust Particulates	Hoods Controlled Air Flow	Filters Dust Collectors	Water or Land	No	Yes	Unknown	Product Contamination	Yes	NA
	Fermenter Vent Gases	--	Incineration	Air	No	No	Unknown	None	Yes	NA

[1] See General Data, Tables A-5-19 and A-5-20, Appendix A-5 pp. A-5-151 and A-5-151A

Table V-12
(Continued)

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
SOLID										
	Radioactive Materials	Control	Collection by AEC Licensed Contractors	Land	Radioactive Material	Yes	Unknown	Radioactive Material	None	None
	Animal Tissue	Autoclaving	Incineration	Land	None	Yes	Unknown	Pathogenic Material	Yes	None
PRODUCT										
	Off Spec Materials	Recycling	--	Recovery	None	No	Unknown	None	Yes	Minor Amounts

Table V-13
Soap, Detergents and Cleaning - SIC-284
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharge to Sewer
WATER	Detergent Mfg. Wastes	Neutralization	Municipal Sewer	Water	Surfactants Polyphosphates	No	40-100#/1000#	None	Unknown	Unknown
	Fatty Acid Wastes	Strippers Catalyst Recycle	Activated Sludge Lagooning	Water	Al, Cu, Cr Oxides	No	Unknown	Water Pollutant	Unknown	Unknown
AIR	Spray Dry Cleaning Mists and Gases	--	Cyclone Collectors	Recycle Dusts	None	No	Unknown	Air Pollutant		
PRODUCT	Surfactants Detergents	--	Municipal Sewers	Water	Phosphates Alkane Sulfonates	No	8-10 billion # annually	Water Pollutant		

Table V-14
Paints, Varnishes, Lacquers, Enamels - SIC-285
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER	Pigment Wastes	Sedimentation	Municipal Sewer Settling Ponds	Water Land	Metal Salts	No	Unknown	None		
AIR	Solvent Wastes	Recycling	Recovery	Process	None	No		None		
			Venting	Air	Toxic Chemicals	No		Toxic Fumes		
			Incineration	Air	None	No		None		
PRODUCT	Lead Paints	--	None	Land	Lead	No	Unknown	Lead Ingestion		
	Solvent Residues or Emissions	--	None	Air	Toxic Solvents	No	Unknown	Air Pollutant		

Table V-15
Agricultural Chemicals, Fertilizers - SIC-287
Waste Streams and Treatment Procedures
(30×10^6 tons produced annually)

Waste Media	Type Waste	Typical Pre-treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER										
	Phosphorus Wastes	--	Sedimentation Lime Precipitation	Landfill	Sulfuric and Phosphoric Acids	None	5 tons gypsum waste/ ton super phosphate produced	None	60%	.8%
	Ammonium Nitrate Dusts	--	Sedimentation	Landfill	Explosive Dust	None	1#/1000# product	None	Unknown	Unknown
AIR										
	SO_x	--	Scrubbers	Lagoons	Weak Acid	None	Unknown	Air Pollutant		
	Phosphate Dust	--	Bag Collection	Recycled	None	None	Unknown	Air Pollutant		
	SiF_4	--	Scrubbers	Lagoons	Fluorides	No	Unknown	Air Pollutant		
	NO_x	--	Scrubbers	Water	Nitric Acid	None	Unknown	Air Pollutant		

Table V-16
Agricultural Chemicals, Pesticides - SIC-287 Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER										
	Organic Phosphorus Wastes	Recycle	Sedimentation Lagooning	Landfill	Residual Toxic Chemicals	Yes	< 1-2% production	Water Pollutant	Unknown	Unknown
	Fungicides Copper Sulphate Mercury Compounds	Recovery	Sedimentation	Landfill	Residual Chemicals	Yes	<1-2% production	Water Pollutant	Unknown	Unknown
	Insecticides Arsenates Spend Acids	Recovery	Sedimentation	Landfill	Residual Chemicals	Yes	Unknown	Water Pollutant	Unknown	Unknown
	Herbicides Acid Wastes	Recycling	Lagooning	Water	Acid Trace Organics	Yes	Unknown	Toxic Chemicals	Unknown	Unknown
PRODUCT										
	Packaged Insecticides Herbicides Fungicides	None	Discarded to Trash	Landfill Incineration	Toxic Chemicals	Yes	>10x10^9# produced	Leach from Landfill	Unknown	Unknown

Table V-17
Primary Metal Industries - SIC-331
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER										
· Ammonia Still Effluent	Phenols Sulfur Ammonia Chlorides	Liquid Extraction Gaseous Extraction	Recycling Biological Deep Well	Water Deep Well	Organic Compounds	No Yes		Water Pollutant		
· Light Oils	Phenols Cyanide Oil	Separators Incineration	Chemical Biological	Water	Organic Compounds	No		Water Pollutant		
· Coke Quench Water	Phenols Cyanide Solids	--	Sedimentation Biological	Water	Organic Compounds	No	10-15,000 gallons/ton with suspended solids of 150-200#/ton	Water Pollutant	Primary 83% Secondary 28% (Industry Average)	<2%
· Pickling Rinses	Acids Oil Iron Scale	Sedimentation Regeneration	Neutralization Lagooning Deep Well	Water Deep Well	Acids Acids	Yes		Water Pollutant		
· Plating and Coating	Chrome Cyanides Acids Alkalis	Reduction Neutralization	Neutralization Sedimentation	Sludge Pile	Metallic Salts	No		Water Pollutant		
AIR										
· Gas Wastes	CO_x NOx SDx Particulates	Settling Chambers Wet Scrubbing Collectors Collectors	Collection of Particulates	Sinter and Sludge	Air Pollutants None	No	400#/ton	Unknown	Unknown	NA
	Organic Compounds	By-Product Recovery	Recovered for Chemical Production	Product	Waste Water Effluent	No	Unknown	Water Pollutant	Unknown	Unknown

Table V-17
(Continued)

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
SOLIDS										
. Slag	Oxides Sulfur Iron	Crushing	Sale Landfill Recharged	Land	Cyanides Florides	No	1600#/ton (total slag)	Leaching	Yes	No
. Sludge	Salts Oxides Sulfates	Sedimentation	Drying	Landfill	Cyanides Florides	No	Unknown	Leaching	Yes	No
. Scale	Metals Oils Scale	--	Recover in Sinter Plant	Sinter	None	--	--	--	Yes	No
PRODUCT										
.	Cyclic Intermediates Commercial Chemicals Household Chemicals			See Petro-Chemicals						

Table V-18
Non-Ferrous Metals - SIC-333
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard
WATER								
Copper	Mining Refining	Neutralization	Tailing Ponds	Landfill	No	No	See Solids	None
Zinc-Lead	Mining	Neutralization	Tailing Ponds	Landfill	No	No	See Solids	None
Aluminum	Red Mud	--	Tailing Ponds	Water	No	No	3.5 tons/ton Al	Water Pollutant
	Brown Mud	--	Tailing Ponds	Water	No	No	--	Water Pollutant
	Oil Emulsions	--	Sewage	Water	Yes	No	--	Water Pollutant
Foundaries								
Fabricators	Pickle Rinses	--	Sewage	Water	Metallic Salts Acids	No	40#/ton	Water Pollutant
AIR								
Copper	SO_2 Dusts Trace Elements	--	Scrubbers Collections Precipitations	Air and Landfill	SO_2(80%0	No	1500#/ton copper	SO_2 Fumes
Zinc-Lead	SO_2 Dusts Trace Elements	--	Scrubbers Collections Precipitations	Air and Landfill	SO_2 (60%)	No	1000#/ton zinc-lead	SO_2 Fumes
Aluminum	Dusts CO_2 Fluorides Aluminum Chloride Chlorine	Collectors --	Precipitation Scrubbers	Recycle Water and Air	Fluorides None Chlorides	No	15-30#/ton aluminum	Vegetation
Foundaries	Zinc & Other Metal Fumes	Hoods	Vents	Air	Toxic Metals	No	--	Toxic Fumes
	Dusts	--	Collectors	Landfill	None	Yes	--	--

Table V-18
(Continued)

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard
SOLIDS								
Copper	Mine Tailings	--	Tailing Ponds	Landfill	No	No	300 ton/ton copper prod	
	Mill Tailing	--	Tailing Ponds	Landfill	No	No	120 tons/ton copper prod	Leaching
	Refining Slage and Slimes	--	Sludge Piles	Landfill	No	No	3 ton/ton copper prod	
Zinc-Lead	Mine Tailings		Tailing Ponds	Landfill	No	No	3. 5 tons/ton zinc-lead prod	
	Mill Tailings		Tailing Ponds	Landfill	No	No	20 tons/ton prod	Leaching
	Refinery Slags		Sludge Piles	Landfill	No	No	400#/ton prod	
Aluminum	Red Mud Brown Mud	--	Tailing Ponds	Landfill	No	No	3. 5 tons/ton prod	Water Pollutant
PRODUCTS								
Aluminum Fluoride								
Aluminum Oxide								
Arsenic & Cmpds								
Barium Salts								
Beryllium & Compounds								
Cadmium & Compounds								
Chromium & Compounds								
Copper & Cmpds								
Lead & Cmpds								
Mercury, Magnesium & Manganese Compounds								
Nickel & Cmpds								
Zinc Compounds								

Table V-19
Coating, Engraving (Plating) - SIC-347
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER	Annodizing -Chromic Acid -Sulfuric Acid -Oxalic Acid	Reduction of Hexavalent Chromium Neutralization	1 Mingled with Sewage (Most Plants)	Water	Metallic Salts Cyanides	No		Water Pollutant	Unknown	
	Phosphating -Metallic Phosphates							Water Pollutant	Unknown	
	Chromating -Acids -Alkalies -Sulfates -Nitrates -Acetates -Chrome	Reduction of Hexavalent Chromium	2 Integrated Treatment (Some Plants) 3 Untreated (Some Plants)	Water	None	--	15-20,000 metal finishing establishments distributed in all population centers	Water Pollutant	Unknown	>75
	Electroplating -Alkali-cyanides -Acids -Chrome -Zinc -Cadmium	Cyanide Removal		Water	Metallic Salts Cyanides Acids Alkalis	No		Water Pollutant	Unknown	
	Metal Finishing -Oils -Acids -Metals	Skimming Sedimentation	1 Sewage	Water	Oils Cyanides	No		Water Pollutant	Unknown	
	Galvanizing -Zinc Cyanides -Zinc Sulfates		2 Plant Sludges	Landfill	Cyanides Metallic Salts	Yes		Water Pollutant	Unknown	

Table V-19
(Continued)

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
AIR										
	Solvents	--	Controlled Venting	Air	Toxic Fumes	No	Unknown		Unknown	NA
	Acid Mists	--	Scrubbers	Landfill	None	--	Unknown	Toxic Fumes and Dusts		
	Metallic Dusts	--	Dust Collectors	Landfill	None	--	Unknown			
SOLIDS										
	Sludges Metallic Chips and Dust	--	Sludge Piles	Landfill	Metallic Salts Acids and Alkalis	Yes	Unknown	Leaching	Unknown	NA
PRODUCT										
	Plated Products	--	Recycled							

Table V-20
Cyclic Intermediates - SIC-2815
Industrial Organic Chemicals - SIC-2818
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER (The wastes listed are examples of typical waste streams)	Organic Waste Acids	Solvent Extraction Distillation	Neutralization Activated Sludge	Landfill	Sludges	Unknown	Toxic Tar Acids		
	Analine Wastes -Acid -Sludges -Aniline	--	Neutralization Activated Sludge	Landfill	Sludges	> 2% analine loss > 20x106#/yr	Toxic Chemicals		
	Alkylation Wastes -Caustics -$AlCl_3$	--	Neutralization Lagooning	Landfill	Sludges	>10x10^9#/yr	Caustics	2815 Primary 48%	2815 4%
	Isocyanate Wastes -Ureas -Carbamyl -Chloride	Recovery	Incineration	Air	None	Unknown	Air Pollutant	2818 Secondary 10%	2818 .2%
	Nitrobenzene Acidic Wastes	Steam Stripping	Neutralization	Water	No	Unknown	Organic Residues		
	Phenol Waste Acids	Distillation	Neutralization Activated Sludge Incineration	Landfill	Sludges	>10x10^8#/yr	Phenolic Residues		
	Styrene Wastes	Distillation	Neutralization Biodegradation	Water	None	>1x10^8#/yr	Organic Chemicals		
	Acidic Dye Wastes	--	Neutralization Sedimentation	Water	None	>1x10^7#/yr	Organic Chemicals		
	Chlorinated Hydrocarbon Wastes	Distillation	Neutralization	Water	Spent Analysts Solids	>1x10^8#/yr	Chlorinated Hydro-carbons		

Table V-20
(Continued)

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER (Continued)									
	Polymerization Wastes	Distillation	Neutralization Lagooning	Landfill	Slimes	>1x10^8#/yr	Phosphates		
	Ethylene Oxide Wastes	--	Neutralization	Water	No	Unknown	Organic Chemicals		
AIR									
	Hydrocarbons	--	Scrubbers Filters	Landfill	Filter Cakes Scrubber Solids	>2% of volatile products--estimated as 10x10^9#/yr	Air Pollutant	Unknown	No
	NO_x Ammonia SO_x	--	Scrubbers Filters	Landfill	Filter Cakes Scrubber Solids	Unknown	Air Pollutant	Unknown	NA
PRODUCT									
	Residuals of All Organic Chemicals Packed and Shipped	--	Municipal Landfill Incineration	Landfill Air	Yes No	<1-2% of total production (120x10^9#)	Toxic, Flammable Explosive Chemicals None	Unknown	Unknown

Table V-21
Industrial Inorganic Chemicals - SIC-2819
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard
WATER								
Sodium Carbonate (4,200,000 tons/year)	Calcium Chloride	--	Settling	Water	Calcium Brine	No	1.5-2 T/ton prod	Water Pollutant
Sodium Hydroxide (2,000,000 tons/year)	Mercury Cell Wastes	--	Amalgam Decomposition	Water	Mercury	No	.1-.2#/ton prod	Mercury in Fish
Thallium Oxide (660,000 tas/yr	Copperas Monohydrate Sulfuric Acid	Recovery	Neutralization	Water Land Ocean	Iron Sulfates	Yes	900,000 tons waste annually 200-300,000 barged to sea	Water Pollutant
AIR								
Hydrochloric Acid (2,000,000 tons/year)	Chlorination Waste Gases	Recycling	Recovery Absorbers Scrubbers	Air	Acid Chlorine Chloriwater Hydrocarbons	No	.1-.3% Loss	Air Pollutant
Chlorine (9,000,000 tons/year)	Waste Gases	--	Scrubbers Absorbers By-Product Production	Air	Chlorine	No	1-2% loss	Acute Reaction
Phosphoric Acid (7,000,000 tons/year)	Fluorides Acid Mist	Collection	Scrubbing	Air	Fluorides	No	.05-.1#/ton	Air Pollutant
Nitric Acid (7,000,000 tons/year)	NO_x	Collection	Absorption Adsorption Reduction Planning	Air	NO_x	No	.4% loss	Air Pollutant
Sulfuric Acid (30,000,000 tons per year)	SO_x	Collection	Scrubbers	Air	SO_x, NO_x	No	.1-.2% loss	Air Pollutant
Phosphate Fertilizers (5,000,000 tons per year	Dusts SO_x Fluorides Ammonia	Collection	Scrubbers	Air	Fluorides SO_x	No	.1-.4#fluorides/ton other unknown	Air Pollutant

Table V-22
Explosives - SIC-2892
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard	Fully Treated On-Site	Discharged to Sewer
WATER										
	Smokeless Powder Wastes (H_2SO_4, Sulfates, NO_x BOD)	--	Neutralization Sedimentation	Water	Acid Residues	No	>$2x10^6$# annually		54%	None
	TNT Wastes	--	Tertiary Treatment	Water	TNT	Yes	>2%$x10^6$# annually		54%	None
	Nitroglycerine H_2SO_4 HNO_3 NO_x BOD	--	Neutralization Sedimentation	Water	Acid Residues	No	>$1x10^6$# annually		54%	None
	Red Water	--	Neutralization Color Removal	Water	Acid and Dye Residues	No	>8#/1000# product		Unknown	None
SOLID										
	Nitro-cellulose & Packing	--	Incineration	Land	None	No	>$700x10^3$#/yr.	None	Yes	
	Methy Nitrate (RDX Waste)	--	Incineration	Land	Methyl Nitrate	Yes	1#/1000 # product	Toxic Chemical	Unknown	
AIR										
	Tetranitromethane (TNM)	Recycling	Scrubbers	Air	Product	No	Unknown			
PRODUCT										
	Contamination Packaging	--	Burning	Air	HCl Toxic Organics	No	7 x 10^6 # / yr.	None		
	Munitions	--	Demilitarization	Air Deep Water Dump	None	No	20,000,000#/yr.	Explosive None		

Table V-23
Department of Defense
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors	Potential Hazard
WATER								
	Explosive Mfg. Wastes -Acids	--	Neutralization	Water	None	No	Unknown	None
	Chemical Mfg. Wastes -Chlorides -Fluorides -Phosphates -Nitrates -Sulfates	--	Lagoons	Water	Inorganic Salts	No	130×10^6 gallons	Water Pollutant
			Evaporation Incineration	Land	Inorganic Salts	Yes	12×10^9 cu. ft. contaminated soil	Leaching
	Incendiaries Mfg. Wastes -Phosphorus -Magnesium and Aluminum Salts	--	Coagulation and Lagoons	Water	Phossy Water	No	200×10^6 gallons	
AIR								
	Explosive Mfg. Explosive Burning -NO_x -SO_x -Particulates	--	Venting Scrubbers Filters Precipitations	Air Land	Yes None	No No	Unknown	Air Pollutant
	Chemical Mfg. -NO_x -SO_x -HCl, HF	--	Venting Filters Scrubbers	Air Land	Yes None	No No	Unknown	Air Pollutant
	Fuels and Lubrication Wastes -Vapors -NO_x -SO_x -Particles	--	Venting	Air	Yes	No		Air Pollutant

Table V-23
(Continued)

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification	Potential Hazard
SOLIDS								
	Explosive Munitions	--	Demilitarization	Land	None	No	80-130,000 tons awaiting disposition	Explosive
			Sea Dumps	Water	Unknown	No		
			Open Pit Burn	Air	Air Pollutants			
	Chemical Munitions	--	Neutralization Incineration	Air Land	Air Pollutants Salts	No Yes	7-8000 tons	Air Pollutant
	Fuels & Lubricants Wastes	--	Dilution	Water	Water Pollutant	No	20×10^6 gallons per year	Air and Water Pollutant
			Incineration	Air	Air Pollutant	No		
			Landfill	Land	None	No		
PRODUCT								
	Pesticides	--	None		Pesticide Containers	Yes	3,000,000# powder 2,000,000 gallons liquid awaiting disposal	Air and Water Pollutants

Table V-24
Radioactive Waste AEC
Waste Streams and Treatment Procedures

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors[2]	Human Exposure[3]	Potential Hazard
WATER									
(Micro Curic/ml $>10^3$)	Hi-Level Chemical Reprocessing Spent Reactor Fuels		Concentrate and Contain	Underground Storage	Radioactive Long-Life Materials	Yes	See Below and Appendix A-12	No	--
(Micro Curic/ml 10^{-3} to 10^3)	Intermediate Fuel Declad-ding Solvent Extraction		Separation into Hi-level and Low-level fractions[1]	Land Burial Sea Disposal	Radioactive Long-Life Materials	Yes		No	--
(Micro Curic/ml $>10^{-3}$)	Low Level Power Reactor Wastes Lab Wastes Medical Wastes	--	Delav & Decay	Land Burial Sea Disposal	Radioactive Long-Life Materials	None		No	--
	Machining & Metal Cleaning of Fuel Elements	Precipitation Filtration	Dilute & Disperse	Tailing Ponds	Radioactive Short-Life Materials	None		No	--
AIR									
	Chemical Fumes Entrained Uranium	Wet Scrubbing	Ponding	Water	None	No		No	--

[1] Waste Treatment processes at Reactor Sites typically include: Evaporators, Gas Strippers, Ion Exchangers, Drumming, Incineration, Storage Tanks.

[2]

		1970	1975	1980
Power Reactor Wastes	Liquid (cu. ft.)	30,000	170,000	330,000
	Solid (cu. ft.)	120	2,300	13,500
Fuel Processing Wastes	if Liquid (gal.)	17,000	970,000	2,700,000
	if Solid (cu. ft.)	170	9,700	27,000
Miscellaneous	Solid (cu. ft.)	51,000	256,000	675,000

[3] If packaged, stored, collected, processed, and contained in accordance with AEC requirements.

Table V-24
(Continued)

Waste Media	Type Waste	Typical Pre-Treatment	General Treatment	Disposal Media	Toxic Residue	Collectable Residue	General Quantification Factors[2]	Human Exposure[3]	Potential Hazard
AIR (Continued)									
	Radioactive Particulates (Laboratories)	Filters	Containment	Land	None	Yes		No	--
	Fuel Processing	Aging	Filters Activated Charcoal Caustic Scrubbing Packed Columns	Land	Radioactive Solids	Yes		No	--
SOLID									
>2R/hr	High Hazard Reactor Fue Fuels		Concentrate and Contain	Underground Storage	Radioactive Long-Life Materials	Yes		No	--
.05-2R/hr	Intermediate HA2 Solvent Extractor	Decontamination Recovery	Separation into Fuels (Hi-Level) and Wastes (Low-Level)[1]	Land and Sea Burial	Radioactive Long-Life Materials	Yes		No	--
<.05R/hr	Low Level HA HA2 Mining Wastes Mill Wastes	Neutralization with Barrium Sulfate	Dilute and Disperse	Water Streams	Radioactive Short-Life Materials	No		No	

[1] Waste Treatment processes at Reactor Sites typically include: Evaporators, Gas Strippers, Ion Exchangers, Drumming, Incineration, Storage Tanks.

[2]

		1970	1975	1980
Power Reactor Wastes	Liquid (cu. ft.)	30,000	170,000	330,000
	Solid (cu. ft.)	120	2,300	13,500
Fuel Processing Wastes	if Liquid (gal)	17,000	970,000	2,700,000
	if Solid (cu. ft.)	170	3,700	27,000
Miscellaneous	Solid (cu. ft.)	51,000	256,000	675,000

[3] If packaged, stored, collected, processed, and contained in accordance with AEC requirements.

4. A METHOD FOR ESTIMATING WASTE STREAM TREATMENT REQUIREMENTS

There is an indeterminate number of waste streams that may result from industrial production operations. Some are relatively pollution-free while others introduce major pollutants into the environment. A method is suggested here through which the extent of treatment needed to reduce pollutants to acceptable levels can be established by a comparison of their characteristics with those that can be successfully treated in municipal sewage plants.

To make this approach workable, a means is needed to readily and accurately define the hazards associated with particular waste streams and to establish their disposal treatment requirements. The following paragraphs describe methods which can be used to rapidly evaluate the effluent data obtained by the Corps of Engineers (through the Refuse Act of 1899) and to identify and quantify the disposal tasks and costs indicated by evaluation of each waste stream.

This approach is based on a comparison of the waste stream characteristics against a standard criteria, i.e., acceptability of such wastes by a typical municipal system. More rigid criteria can be applied, of course, but the likelihood of increased use of municipal-type treatment systems by industry indicates that municipal acceptance standards may be practical criteria.

Additional rationale for the use of municipal sewage acceptance standards include:

- Wastes treated in municipal sewage treatment plants show similar characteristics from one locale to another.
- A standard, and national, technology has been developed for this type of waste. The technology is particularly well established for primary and secondary treatment.
- Municipal sewage treatment plants are demonstratively capable of producing effluents that, to date, appear to satisfy ecological preservation requirements.

- If industrial wastes can be treated so that they are acceptable for further treatment in municipal facilities, they too should be non-damaging to the ecology when processed through the municipal plant.

Pretreatment of the waste stream to make it eligible for municipal plant treatment may not be needed, may require minimum treatment, may require extensive treatment, or some components may be so toxic that only their removal will permit successful pretreatment.

The rating system which is outlined in the following tables and text is based on establishing the treatment level required to meet each of the key criterion. The more treatment necessary, the higher the numerical rating for that criterion. When all criteria are rated, the ratings for each characteristic provide a weighted profile of the special treatments necessary to qualify the waste for municipal treatment.

Table V-25 outlines a means for establishing the level of treatments needed to qualify an industrial effluent stream for final disposal through a municipal treatment plant. Table V-26 provides an example as to how the rating system works. The expected reductions that can be achieved by the various treatments are shown in Table V-27.

Table V-25 indicates the acceptance criteria for each key waste characteristic and defines the percentage of removal efficiencies which must be achieved in order to meet the criteria. For example, if BOD had to be lowered by 85 percent to reach acceptable level, a minimum of secondary treatment would be required and a score of 3 would be assigned. If 99 percent of the phenol had to be removed, tertiary treatment to achieve this level would be required, and a rating of 4 would be given for this characteristic. When all characteristics are rated, a profile emerges which indicates the extent of treatment necessary and serves as a rating as to the extent and type of hazard contained in the wastes.

The rating system identifies treatment requirements as a function of the concentration of key waste characteristics and/or problem contaminants. The higher the concentration of a given waste parameter, the more intensive will be the abatement effort required, and, similarly, the higher the concentration of a given waste parameter, the greater is the hazard potential of the stream. Hence, the system combines hazard potential with treatment complexity.

Table V-25
Rating Guideline Sheet

Waste Parameters		BOD[1] ppm	SS ppm	pH	Oil ppm	Phenol[2] ppm	Heavy Metals ppm	Other Parameters	Remarks
Acceptable Industrial Wastewater		300	350	4.5 - 9.5	100	20	See Note 3	See Note 3	
Average Efficiency and Type of Treatment									Cost[6], $/million gal. 100 mgd Plant
Treatment[4]	Treatment[5] Rating								
No Treatment	0								
Primary	1	30%	65%		90% Floating			Dump Rate, Temperature	Primary $ 50
Intermediate	2	75%	85%	Adjust	50% Emulsified		95%	CN, NH_{3-4}, NO_{2-3}, Phosphates, Sulfide	Intermediate $105
Secondary	3	85%	90%		85%	85%			Secondary $105
Tertiary/Special	4	95%	95%			99%	99% Chromates	Antibiotics, Cresols and Creosotes, Herbicides, Pesticides, Sulfonamides, Strong Oxidizing and Reducing Agents, Toxic Dyes	Tertiary $190

Notes:
1) BOD or COD not to exceed 300 ppm.
2) Completely aerated activated sludge can biodegrade up to 2,000 ppm phenol.
3) Acceptance Limits on Heavy Metals and Selected Other Parameters - Limits on other parameters are 10 ppm.

Parameter:	Cd;	Cr;	Cu;	Hg;	Ni;	Zn;	Residual Br, Cl, I;	CN;	Control Dump Rate @ TS;	Temperature
Limit, ppm:	5;	5;	5;	2;	3;	5;	100 ;	2 ;	10,000 ;	150°F

4) See Table 5-3 for an in depth discussion of treatment details and efficiencies.
5) Scoring was developed in the order of increasing complexity and cost of treatment technology
6) Cost includes capital, maintenance and operation. From Reference F.
7) References:
   A. Industrial Pollution Control Handbook, LUND, 1971.
   B. Manual of Instruction for Sewage Treatment Plant Operations, State of New York
   C. "Standards for Sewage Works." Upper Mississippi River Board of Public Health Engineers.
   D. New York City Administrative Code.
   E. The Cost of Clean Water, Volume III, Industrial Waste Profile, Numbers 1-10, FWPCA, Sept. 1967.
   F. AIChE, Industrial Process Design for Water Pollution Control, Vol. 3, 1970.

Table V-26
Rating Worksheet - How to Use Rating System

Waste Parameters	BOD ppm	SS ppm	pH	Oil ppm	Phenol ppm	Heavy Metals ppm	Other Parameters ppm	Remarks
Acceptable Industrial Wastewater	300	350	4.5-9.5	100	20	See Guideline Sheet Note 3		
Example (1) Waste Profile Treatment Profile	500 1	400 1	3 2	- -	- -	20.0 ppm Cr 2	50 ppm CN 2	This waste profile indicates that the stream needs immediate chemical treatment.
Example (2) Waste Profile Treatment Profile	1,500 3	400 1	6 0	650 1	500 3	- -	- -	This waste profile indicates that the stream needs secondary (biological) treatment
Example (3) Waste Profile Treatment Profile	400 1	150 1	- -	- -	300 3	- -	350 ppm pesticides 4	This waste profile indicates that the stream needs tertiary treatment

How to Use Rating System:

A) Indicate analysis of wastewater under the appropriate heading, BOD, SS, etc. List waste parameters (which cannot be included under the six specific headings provided) under the "Other Parameters" column.

B) The scoring is based on the type of treatment that is required to bring the waste within "Acceptable Industrial Wastewater" standards. The efficiency figures from the Rating Guideline Sheet gives guidance as to what treatment will accomplish this.

C) Check against the Guideline Sheet, "Other Parameters" column, to see if the waste contains any of the entries listed under this heading. If yes, enter scores of 1, 2, or 4 depending on which treatment row the entry appears in.

Table V-27
Removal Efficiencies of Waste Treatment Processes

WASTEWATER TREATMENT METHOD	GENERAL EFFICIENCY Percent					EXAMPLES OF EFFICIENCY IN SPECIFIC APPLICATIONS	REF
	BOD	SS	P	N	COD		
PRETREATMENT	5-10	5-10					
Screening							
Degritting							
Comminuting						Tanning: BOD-5%; SS-5 to 10%	3
Grease and Scum Removal							
Pre-Aeration							
Equalization/Dump Rate Control						90% Grease Removal Some BOD removal	
						Tanning: Chromium-5 to 10%	9
						Some Self-Neutralization Sedimentation and BOD Reduction	3
PRIMARY TREATMENT (Including Pretreatment)	25-50	65					
Conventional Gravity Separation	25-50	65					
						Blast Furnace & Sintering Plant: SS-94%; Hot Rolling Mills: SS-91%; Lube Oils-20%; Tanning: BOD-25 to 62%; SS-69 to 96%; Sulfide-5 to 20%	1 2, 3
Advanced Conventional plus Chlorination Detention	40-50	65				Paper Mill: SS-70 to 90%	6
						Chlorination of raw sewage: BOD-15 to 25%	9
INTERMEDIATE TREATMENT (Including Primary Treatment)	50-95	80-95	88-95				
Flotation							
Filtration (Rapid Sand)	95	95				Emulsified grease: >50%	
Adsorption (Activated Carbon)							
						Organic Chemicals and Pesticides: Cresols-99%	9
Chemical Treatment - Clarification (Chlorination)	50-70					Cyanide Removal with pH Adjust. and Chlorination: >99%	10

Table V-27
Continued

WASTEWATER TREATMENT METHODS	GENERAL EFFICIENCY Percent					EXAMPLES OF EFFICIENCY IN SPECIFIC APPLICATIONS	REF
	BOD	SS	P	N	COD		
INTER. TREAT. (Cont'd.) Chem. Treat. (Cont'd.) Neutralization, pH Adjust.						Affects Efficiency of Chemical Treatment Activated Carbon, etc.	
Coagulation						Sinter Plant: SS-98%; Hot Rolling Mills: SS-95%; Lube Oils-80%	2
Flocculation Precipitation			88-95			Cotton and Synthetic Textiles: BOD-25-60%; SS-30 to 90%; TDS-0 to 50%	8 7
Oxidation/Reduction							
Chemical Treatment - Clarification (Filtration)	70-80	80-90	95-98			Chromate Removal with Reduction and Precipitation: >99%	1, 9 8
SECONDARY TREATMENT (Including Primary and/or Intermediate Treatment)	65-97	90	60-90	30-90			
Biological Treatment (With Chlorination)				30-50		Oil Refinery: Phenol-65 to 99%; Cyanide-65 to 99%	8, 4
Trickling Filters Standard High Rate	 80-85 65-80					Tanning: BOD-65 to 80%; SS-85 to 90%; Sulfide: 75 to 100%	1, 3
Activated Sludge	85-90		60-80			High strength polymer wastes: BOD-95%; COD-75%; SS-97%	1, 8 1
Lagooning (aerobic) (With Filtration or Other)	90	90				Tanning: BOD-70%; SS-80% Rapid sand filtration: BOD-(80%); SS-(70%)	3 1
Trickling Filters						With Coagulation, Wheat Starch Prod.: BOD-80%; SS-88%; P-80%	11
Activated Sludge	90-97		90	90		With Aerated Lagoon, Corn Milling: BOD-90%; COD-86%; SS-33%	1 11

Table V-27
Continued

WASTEWATER TREATMENT METHODS	GENERAL EFFICIENCY Percent					EXAMPLES OF EFFICIENCY IN SPECIFIC APPLICATIONS	REF
	BOD	SS	P	N	COD		
TERTIARY TREATMENT (Including Secondary or Intermediate)	95-99	95-99	95	95	85		
Ion Exchange			(86-98)	(80-92)		Chromate recovery: >95%	1, 5
Membrane Processes							
Dialysis						Recovery of acids from acid/metals mixtures: 75%	5
Electrodialysis			(30-50)	(30-50)			8
Reverse Osmosis			(65-95)	(65-95)		SS-(95%)	8, 5
Adsorption (Activated Carbon)	(85) 90-99	(90)	(0) 85-90	(0) 85-90	(82)	Activated carbon treatment of sewage treatment plant secondary effluent: BOD-(33%); COD-(80%); SS-(25%); PO_4-(50%); ABS-(97%)	1
Ozonation						Refinery: BOD/COD-(50 to 90%); Phenol and Cyanide-(80 to 99%);	4
Chemical Treatment						Vinyl resin waste (after biological treatment): BOD-94%; COD-85%; SS-90%	
Lime Clarification	(55)	(90)	(90)	(0)	(26)	Lime treatment of sewage treatment plant secondary effluent: BOD-(74%); SS-(80%); PO_4-(95%); ABS-(18%)	1
Combined Systems							
Microscreening and Rapid Sand Filtration	(50)	(70)	(0)	(0)	(20)		1
Lime Clarification plus Multimedia Filtration	(60)	(99)	(90)	(0)	(30)		1
Lime Clarification plus Ammonia Stripping	(55)	(90)	(90)	(87)	(26)		1
Lime Clarification plus Ammonia Stripping plus Granular Carbon Adsorption	(92)	(99)	(90)	(87)	(85)		1

Table V-27
Continued

Legend:

BOD - Biological Oxygen Demand
COD - Chemical Oxygen Demand
P - Phosphates
N - Nitrogen
SS - Suspended Solids

Efficiency percentages with parentheses indicate efficiency relative to the influent (as secondary treatment effluent to tertiary treatment). Efficiency percentages without parentheses indicate efficiency relative to the raw waste.

References:

Table Reference Number	Reference Material
1	AIChE, Industrial Process Design for Water Pollution Control, Vol. 3, 1970
2	The Cost of Clean Water, Volume III, Industrial Waste Profile, Number 1 Blast Furnaces and Steel Mill, FWPCA, Sept. 1967
3	The Cost of Clean Water, Volume III, Industrial Waste Profile, Number 7, Leather Tanning and Finishing, FWPCA, Sept. 1967
4	The Cost of Clean Water, Volume III, Industrial Waste Profile, Number 5, Petroleum Refining, FWPCA, Nov. 1967
5	Industrial Pollution Control Handbook, LUND, 1971
6	NIPCC Sub-Council Report - Paper, March 1971
7	The Cost of Clean Water, Volume III, Industrial Waste Profile, Number 4, Textile Mill Products, FWPCA, Sept. 1967
8	Pollution Abatement Engineering Program for Munition Plant Modernization, Army Research Office, Sept. 1971
9	Manual of Instruction for Sewage Treatment Plant Operations, State of New York
10	"The Use of Activated Charcoal In the Treatment of Trade Wastes," British Chemical Engineering, pp 107-110, Feb. 1961
11	Industrial Waste Study Report - Grain Mill Industry, Sverdrup and Parcel and Associates, Inc., Aug. 1971

The rating system can find practical application in the following areas:

- Serve as a basis for defining a hazardous industrial effluent.
- Identify particularly hazardous wastes.
- Serve as a logic basis for computerized evaluation of the massive data accumulated regarding the 1899 Refuse Act. This can be done as a function of:
  - Region
  - Industry group(s)
  - Water usage ranges
  - Treatment level (none, primary, secondary, tertiary or special)
  - Treatment economics
  - Specific waste characteristics
  - Combinations of the above.
- Provide fundamental information for policy making:
  - Should a plant or a group of plants treat effluents onsite or combine with municipal systems?
  - Should private industry band together to build a cooperative treatment complex?
  - Should government provide incentives or hardware for cooperative waste treatment and residue handling arrangements?

Hazardous wastes can be defined and rated based on this system, i.e., a hazardous industrial effluent is one that does not satisfy the criteria for acceptance into municipal sewage treatment plants. If this system were established, each plant would be required to treat its wastes to a level which will qualify for acceptance into a municipal system, if avaiable, or to treat it onsite (or in some cooperative arrangement) to a level that assures compliance with regulations regarding discharge into public water bodies. In other words, the amount of treatment needed to make any waste acceptable to a municipal sewage treatment plant can be assigned specific values, and these values used to establish an index of the toxicity of that waste, at the particular location for which it is being rated.

The system proposed is a more thorough system for defining hazardous waste streams than is any list of potentially hazardous materials or waste streams. This system deals with an actual condition, measures it against the environmental acceptability, and defines the corrective action necessary. Because it is designed to deal with specific waste streams, it avoids the generalities of designating certain substances as potentially hazardous and assuming that they will be hazardous whenever present. "Hazardous waste materials" are hazardous only when in sufficient concentration to exceed the threshold effects of susceptible life forms. Until disposal systems planning is based on specific situations and locations, it cannot control the release of hazardous wastes.

The practical value of this evaluation method is that it establishes the level of treatment which is required to make the waste stream a nonpolluting effluent. The identification of treatment needs does not reduce the amount of hazardous wastes that are discharged, however. The identification of treatment requirements is relatively meaningless, unless a means exists to enforce legal restraints on hazardous waste releases.

5. RATING CURRENT TREATMENT AND DISPOSAL METHODS

The waste treatment methods which are used most widely are general in nature, can be applied to a variety of processes and waste compounds, and are concerned with water waste streams. Historically, water has been used to remove contaminants from production facilities either by its use as a wash or by its use directly or indirectly (costing) in the production process. As a diluent it is a means to reduce the concentration of hazardous wastes and lessen its impact on the environment.

Because water plays such a large part of our current treatment methods, the volume which is involved is substantial. Any attempt to transport such water streams over long distances for treatment will involve substantial expense. Therefore, the tendency will be to treat water waste streams on the site where the wastes are created or within a relatively few miles of such sites. However, if wastes must be transported over long distances for disposal (sea disposal, lagoons), pipelines are an economical movement system in comparison to rail, truck or barge transportation.

Once introduced into water waste streams, hazardous materials are difficult to remove. If the introduction of such wastes creates significant treatment problems, they can be segregated and treated separately. Frequently, such wastes are organic compounds which are difficult to biodegrade but which are readily incinerated. Deep-well disposal is also used for such wastes. Many of the toxic materials are organic solvents and are readily destroyed by incineration.

Although the various basic types of treatment and their applications are widely known, there are substantial differences in the design features that best fit them to specific applications. It is this adjustment and fitting process that determines the general types of treatment that will be applied, and the specific features and the design specifications which best adapt these general types of treatment to the specific technical and cost requirements of individual facilities and locations.

The effectiveness of alternative treatment methods cannot be assessed realistically unless evaluated against a specific requirement. Relative efficiencies of different treatments are a preliminary indication of their utility in a specific situation, but the actual requirements and system peculiarities are the only valid basis for selection between alternative methods.

(1) Evaluation Elements

The basic elements in a systematic evaluation of the adequacy of treatment methods for hazardous waste streams are:

- Identification of the specific compounds which compose the waste stream

- Characterization of the waste stream (pH, BOD, SS, phenols, etc.) in quantitative terms
- Identification of the acceptable effluent standards based on the materials contained in the waste stream
- Selection of the alternative treatments which will satisfy the requirements
- Evaluation of the treatment requirements
- Trade-off analysis to identify the most cost-effective treatment sequence
- Feasibility of financing such treatment systems based on the economic realities of the production costs involved.

This general methodology can be applied to a single waste stream, combined waste streams, and to single or multiple disposal sites. If wastes are to be brought to a distant site, the first two factors must be evaluated for each waste stream, the transportation costs to the process site established for each waste stream, and then the last two factors evaluated for the combined waste streams.

Although systematic methodology can be devised to measure, rate, and evaluate the effectiveness of alternative disposal systems in removing hazardous materials from waste streams, such methodology cannot be used to evaluate current practices since the data necessary to operate the evaluation system is not available.

In the absence of detailed data on waste stream characteristics and their treatment needs, only crude evaluations can be made as to the effectiveness of current practices and future treatment requirements. Little information is published concerning the hazardous waste streams which are produced. Conjecture as to their composition and characteristics is based on the hazardous characteristics of "pure" compounds produced and used in industry and in the commercial and household sectors.

(2) Evaluation Problems

An evaluation system that rates the effectiveness of current hazardous waste treatment and disposal practices must cope with several interrelated problems:

- Does a hazardous waste condition exist?
- What is the condition and how serious?
- What steps have been taken to minimize the hazards?
- How effective are these actions?
- What additional steps are necessary?

If answers to these questions can be obtained, the rating system will be able to identify and evaluate the actions needed to adequately control the disposal of hazardous wastes.

The identification of wastes which create hazardous conditions is a complex task. The hazardous condition may be caused by a radioactive, explosive, corrosive, pathogenic or toxic material and its effect is dependent on the susceptibility of the material or living organism exposed to the hazard. Since a hazardous condition exists only when a material is present which exceeds the threshold tolerance of a susceptible material or population, three data elements are needed to define the hazardous condition: the magnitude of the hazardous effect, the susceptibility of the material or population, and the dilution effect of the media that contains the hazard.

The constant factor is the material that creates the hazardous effect. The location where the waste occurs will determine who or what is threatened and the mitigating effects of fortuitous neutralization or dilution. The key to the identification of a hazardous waste condition is the determination that a potentially hazardous material is present in the waste stream in amounts that exceed the tolerance levels of the threatened population or materials.

Analysis of the waste stream to establish its hazardous properties is rather easy for radioactive, corrosive or flammable materials, but is more difficult if the significant hazard is pathogenic or toxic.

An alternative to onsite analysis is knowledge of the characteristics of the chemical components that compose the waste stream or that may enter the waste stream. When toxic materials are present, the possibility that hazardous waste conditions exist must be assumed.

Evaluation of the raw materials used in the production process, the production processes used and the by-product materials expected, can establish a list of potential constituents of the waste streams. Comparison of such compounds with a comprehensive list of toxic materials will identify the hazardous potential of the waste stream and aid in selecting the analytical techniques which can best verify initial assumptions as to hazard potential.

(3) Characterization of Hazardous Conditions

The type waste streams which result from processing operations are dependent on the chemical characteristics of the reactants and the physical conditions under which the reactions take place. Since the combination of reacting compounds and the reaction conditions may vary greatly, the waste products from chemical industry vary greatly. However, when the reactants and the production process are known, the waste product possibilities are greatly narrowed. Without specific raw material and process information, the probable content of the waste stream is indeterminate.

When the processes, raw materials and output quantities are known, useful approximations can be made as to the probable toxic hazards associated with waste streams. Such information has been developed for some industries. Unfortunately, however, the waste streams from such industries frequently are intermingled with those from plants about which little is known, and the combined waste streams become an enigma as to potential toxic effects. Such intermingled waste streams, when they are part of river systems, are no longer the treatment responsibility of specific community or plant, and corrective treatment is no longer feasible.

The waste streams which result from chemical processing are dependent on the chemical characteristics of the reactants and the physical conditions under which the reaction takes place. Process conditions of temperature and pressure modify the physical characteristics of chemical compounds and may convert solids into liquids and gases, liquids into gases, or mixtures of liquids into solids. Side-reactions of compounds may produce unwanted waste by-products. Unless the specific conditions and reactants are known, the content and condition of the waste stream is indeterminate. Compounds which are individually inert, corrosive, flammable, explosive, or toxic under normal conditions, may react with other components and become relatively less dangerous or may be converted from a nonhazardous state to one of substantial hazard.

Knowledge of the chemical compounds involved in or produced by the production process helps identify potentially hazardous wastes. When physical properties of commercial chemicals are known, the hazards associated with each are reasonably predictable. When all the reactants, processes and products are identified, the key hazards and the alternative treatments needed to avoid the release of hazardous wastes are readily identified. The most cost-effective treatment will be dependent on the mix of materials to be treated, quantities to be treated, enforcement standards, and other variables. Unless there is information as to the raw materials, production processes, and final products, no sensible judgment can be made regarding the most cost-effective treatment processes.

The minimum information necessary to define the possibility that hazardous waste conditions exist is (1) an analysis of the effluent stream, and (2) knowledge of the input and output products. Armed with such data, a judgment can be made as to the pollution potential of the waste streams. (The method for evaluating the treatment requirements, based on the effluent analysis, has been described in the previous section.) Specific knowledge of the entire product line, production processes and waste stream is needed for such decisions in order to define the most cost-effective treatment processes.

(4) Treatment Variations

A variety of methods are available to treat waste streams and remove contaminants. The treatment of choice is dependent on the characteristics of the waste stream and those of the material or materials to be removed. If the hazardous compound can be isolated and treated as a single compound, the treatment method will be substantially different than the methods used if the compound is part of a water waste stream. If several contaminants are to be treated while in the same waste stream, the quantity and characteristics of the major contaminants may affect the choice of treatments.

An analogy can be drawn between the decision process involved in diagnosing and treating a sick patient and in diagnosing and treating a hazardous waste stream. In each case, a diagnosis must be made, based on a specific situation, as to the problem to be solved and the most suitable treatment. A variety of treatments are available and must be fitted to the particular needs of the specific situation. The "best" treatment for a specific patient may not be the "best" for all patients.

The list of hazardous materials that have been developed can be used to illustrate how different conditions may effect the selection of the appropriate disposal process. Each of the compounds on this list may require safe disposal under a variety of different disposal conditions, i.e.:

- As part of the disposal process related to its production
- As a major raw material component in the production of other chemical compounds
- As a minor component in a production or commercial treatment process
- As a retail consumer product which enters the municipal disposal system.

Few compounds are used for only one purpose. The use to which the compound is put and its relation to other compounds in the disposal process, will influence the selection of the best waste disposal treatment process.

Examples of the waste treatment methods for sulfuric acid under various conditions may help illustrate this point. During the production process, every effort is made to minimize the loss of sulfuric acid; recovery and recycling of inadvertent wastes is the treatment of choice. In an oil refinery, sulfuric acid is recovered, restrengthened and reused. When used to acidulate phosphate rock to produce super phosphate, every effort is made to insure the complete reaction of the acid with the phosphate rock. A variety of treatments is used to neutralize, recover, or safely dispose of residual acid mixes used to pickle steel. When used as a laboratory chemical, its safe disposal may consist only of careful dilution to acceptable municipal levels.

The treatment methods which apply under specific conditions are dependent not only on the chemical characteristics of the materials involved, but on their relative importance in the disposal process. The disposal means for a specific chemical is tailored to their individual characteristics, i.e., incineration of flammable materials or neutralization of corrosive materials. When they are a component of a generalized waste stream, the treatment methods are less specific and are designed to safely handle a variety of chemicals.

Under certain production conditions, individual compounds may be separated from the remaining waste streams and disposed of by separate action, i.e., solvents may be burned, acids may be piped to a deep well. Separate disposal processes are also used if the incorporation of one waste with another would make the disposal of the combined waste stream more difficult.

In general, when a large number of different waste materials exist, the treatment process of choice is the conventional screening, settling and biological conversion process. Incineration processes are the method of choice for toxic organic wastes which are isolated for separate disposal. Recovery and recycling are used in the production processes to ensure the optimum practical yield from the input materials.

(5) Evaluation of Current Practices

Although a variety of treatment methods have been developed that can treat any identified waste successfully, the use of these methods is not widespread. Full treatment to remove all waste hazards is rare. The costs that are incurred in treating wastes from major production plants are substantial.

The Deepwater Pilot Plant Treatability Study conducted by the Delaware River Basin Commission, illustrates the costs involved. This project had the following objectives:

- To determine the treatability characteristics of the component industrial and municipal wastes (nine plants, four communities)
- To develop design criteria for the facility to achieve 90-95 percent BOD reduction as well as to meet other effluent quality requirements
- To test methods of secondary and advanced waste treatment of combined municipal and industrial wastes
- To estimate cost of construction and operation of the facility
- To provide data on which to base an equitable appointment of cost among the industries and municipalities to be served
- To demonstrate the expeditious and timely resolution of the technical and economic difficulties of achieving a regional solution to a complex multi-industrial and multi-waste disposal problem.

The project has operated for over two years at a cost of over one million dollars. The costs involved in developing this detailed design data are indicative of the level of expenditure needed if treatment requirements are to be established.

The wastes produced in the nine production plants involved in the Deepwater Pilot Plant Treatability Study are typical of the water wastes of chemical industry. The costs to construct a treatment facility to adequately treat 105 million gallons of wastes per day produced in these plants is estimated as approximately $60, 000, 000. Based on these cost estimates, the cost to upgrade all chemical industry treatment facilities will be several billion dollars. These projections of costs based on the Deepwater Pilot Plant Study are unlikely to be accurate but are indicative of the magnitude of the treatment costs which must be incurred to signficantly reduce overall water pollution levels.

The fact that hazardous waste streams are inadequately treated can be established by reviewing data as to the extent of water waste treatment. The tables which follow titled "Industrial Water Treatment Practices" and "Evaluation of Industry Treatment Processes" have been developed from data contained in Water Use in Manufacturing, Bureau of the Census, published in 1971. The value shown under the title "Required Waste Water Treatment," in the second table, is 200 if secondary treatment is required or 300 if tertiary treatments are necessary to remove hazardous materials from the water waste streams of each particular industry. The other columns in this table show the percent of the industry that uses primary, secondary and tertiary treatments. Adding these percentages and dividing by the required rating provides the values shown in the rating column. Note that only the Petroleum Refining industry provides primary and secondary treatment. The percentage of industries providing tertiary treatment is based on estimated values rather than published data.

Table V-28

Industrial Water Treatment Practices
(Data in Billions of Gallons Unless Noted Otherwise)

Industry		Discharged	Discharged to Sewer	Percentage Discharged to Sewer[1]	Process Water	Treated Water	Percentage of Process Water Treated[2]	Primary Treatment[3]	Percentage Primary Treatment[4]	Secondary Treatment[5]	Percentage Secondary Treatment[6]
SIC	Title										
20	Food	752.9	237.5	31.5	290.6	184.7	62.5	88.6	30.5	17.0	5.8
201	Meat	99.5	65.3	65.5	62.3	38.5	61.8	18.5	29.6	6.5	10.4
202	Dairy Products	53.0	31.0	59.5	16.0	2.1	13.1	.8	5.0	.6	3.8
203	Canned, Cured and Frozen	119.8	41.7	34.8	71.0	47.7	67.0	31.1	43.7	4.2	5.9
204	Grain Mill Products	67.1	19.2	28.5	11.8	6.0	50.8	4.4	37.3	.6	5.0
205	Bakery	3.2	1.9	59.3	1.1	.2	18.2	--	--	--	--
206	Sugar	233.0	3.9	1.7	74.1	70.8	95.5	49.0	66.1	6.1	8.2
207	Confectionary	18.6	3.1	16.7	2.5	.9	3.6	--	--	--	--
208	Beverages	97.4	50.5	51.8	19.1	7.4	38.6	1.5	7.8	.6	3.1
209	Miscellaneous	61.0	20.8	34.1	21.0	11.1	52.8	5.1	24.3	.4	1.9
22	Textile Mill Products	136.0	50.6	37.3	109.0	53.7	49.2	30.8	28.1	8.2	7.5
2211	Cotton	27.8	6.0	21.6	19.4	9.5	49.0	2.8	14.4	2.6	13.4
2221	Synthetics	10.9	4.4	40.3	8.1	5.3	65.3	2.4	29.6	3.3	41.2
2231	Wool	14.1	3.6	25.5	11.9	5.9	49.5	3.9	32.7	.2	1.7
26	Paper and Allied Products	2,077.6	72.4	.3	1,477.9	915.3	61.7	565.8	38.3	132.7	8.9
28	Chemicals and Allied Products	4,175.1	181.1	.4	733.4	674.2	92.0	304.1	41.3	87.8	12.0
2812	Alkalis and Chlorine	364.1	47.2	13.0	18.1	117.3	100	22.5	100.0	.3	1.6
2815	Cyclic Intermediates and Crudes	129.0	4.7	3.6	19.3	50.0	100	29.1	100.0	9.1	47.2
2816	Inorganic Pigments	91.5	1.0	1.1	21.2	21.7	100	10.4	49.0	1.0	5.0
2818	Industrial Organic Chemicals	2,033.3	39.2	.2	394.0	142.2	36.0	63.3	16.1	35.6	9.0
2819	Industrial Inorganic Chemicals	468.0	42.6	9.1	75.2	133.4	100	78.5	100.0	8.7	11.6
282	Plastic Materials and Synthetics	581.8	15.3	2.6	104.2	141.5	100	60.2	57.7	29.4	28.2
2821	Plastic Materials and Resins	198.8	12.3	6.2	50.9	31.9	62.5	20.1	60.0	13.5	26.6
2822	Synthetic Rubber	57.9	2.1	3.6	15.1	11.1	100	23.6	100	2.5	16.5
2823	Cellulosic Man-Made Fibers	176.4	.3	.2	30.5	34.8	100	21.0	68.9	12.3	40.3
2824	Organic Fibers	148.6	.6	.4	7.7	33.7	100	8.1	100	1.1	14.2

*SOURCE: Water Use in Manufacturing, Bureau of Census, U.S. Department of Commerce, April 1971.

[1] Percentage of discharged waters sent through municipal sewage.

[2] Percentage of processed water treated prior to release.

[3] Primary Treatment: Neutralization, Sedimentation, Flotation, and Coagulation.

[4] Percentage of processed water receiving primary treatment.

[5] Secondary Treatment: Activated Sludge, Trickling Filters, Filtration, Sedimentation and Digestion.

[6] Percentage of processed water receiving secondary treatment.

Table V-28
(Continued)

Industry		Discharged	Discharged to Sewer	Percentage Discharged to Sewer[1]	Process Water	Treated Water	Percentage of Process Water Treated[2]	Primary Treatment[3]	Percentage Primary Treatment[4]	Secondary Treatment[5]	Percentage Secondary Treatment[6]
SIC	Title										
283	Drugs	67.4	9.8	14.5	6.8	6.3	92.6	2.5	36.8	.8	11.8
284	Soaps, Cleaners and Toilet Preparations	30.3	5.7	18.8	3.5	.6	17.1	.4	11.4	--	--
2851	Paints and Allied Products	6.5	4.6	70.8	2.7	.3	11.1	.2	7.4	--	--
287	Agricultural Chemicals	113.9	.9	.8	28.8	29.9	100	19.0	65.8	.6	2.8
2892	Explosives	143.1	(z)	--	28.0	17.8	62.6	15.0	53.5	.7	2.5
2911	Petroleum Refining	1,210.0	5.5	.5	91.7	917.1	100	682.8	100.0	378.7	100.0
3111	Leather Tanning and Finishing	14.0	9.4	67.2	13.5	9.5	70.3	3.0	22.2	1.4	10.3
3292	Asbestos Products	6.4	.8	12.5	5.0	2.2	44.0	1.9	38.0	1.4	28.0
33	Primary Metal Industry	4,695.5	143.3	3.0	1,207.2	1,430.9	100.0	893.2	62.4	304.4	25.2
331	Blast Furnaces, Basic Steel Production	4,128.8	77.7	1.9	1,049.2	1,355.2	100.0	870.9	83.3	300.7	28.6
333	Primary Non-Ferrous Metals	412.1	12.4	3.0	88.9	36.7	41.3	25.4	28.6	1.4	1.6
3331	Copper	37.3	1.7	4.5	26.8	11.9	44.3	8.8	32.8	--	--
3332	Lead	6.7	(z)	--	5.5	2.2	40.0	--	--	--	--
3333	Zinc	44.1	2.2	5.0	4.1	3.9	95.0	--	--	--	--
3334	Aluminum	199.9	8.2	4.1	23.5	18.3	77.8	10.5	44.6	1.3	5.5
347	Metal Services	8.0	5.9	73.8	7.2	2.0	27.8	.5	6.9	.2	2.8
3471	Plating and Polishing	7.4	5.6	75.6	6.7	1.9	28.3	(D)	--	(D)	--

*SOURCE: Water Use in Manufacturing, Bureau of Census, U.S. Department of Commerce, April 1971.

[1] Percentage of discharged waters sent through municipal sewage.

[2] Percentage of processed water treated prior to release.

[3] Primary Treatment: Neutralization, Sedimentation, Flotation and Coagulation.

[4] Percentage of processed water receiving primary treatment.

[5] Secondary Treatment: Activated Sludge, Trickling Filters, Filtration, Sedimentation and Digestion.

[6] Percentage of processed water receiving secondary treatment.

Table V-29

Evaluation of Industry Treatment Practices

			PRESENT PRACTICE				
	Industry	Required Waste Water Treatment[1]	Percentage[2] Primary	Percentage[2] Secondary	Percentage[3] Tertiary	Total Value	Rating[4]
20	Food	200	30	6	—	36	18
22	Textile	300	31	8	<2	41	14
26	Paper	200	38	9	—	47	24
2812	Alkali-Chlorine	200	100	2	—	102	51
2815	Cyclic Intermediates	300	100	47	<10	157	52
2818	Organic Chemicals	300	16	9	<5	30	10
2819	Inorganic Chemicals	200	100	12	—	112	56
282	Plastics	300	58	28	<5	91	30
283	Drugs	300	37	12	<5	54	18
284	Soaps and Cleaners	200	19	—	—	19	10
285	Paints	300	71	—	—	71	24
287	Agricultural Chemicals	300	66	3	<2	71	24
289	Explosives	300	54	3	<2	59	20
29	Petroleum Refinery	300	100	100	<25	225	75
31	Leather	300	67	1	—	68	25
32	Asbestos	200	38	28	—	66	33
331	Basic Steel	300	62	25	<2	89	30
333	Non Ferrous	300	27	2	<2	31	10
347	Plating	300	76	3	<2	81	27

(1) To remove all hazardous compounds, secondary 200, tertiary 300.
(2) Percentage of water wastes treated based on census data.
(3) Estimates.
(4) Total value column divided by required waste water treatment (200 or 300)

The limited data on the extent of treatment of air waste streams precludes any general assessment of the extent of air waste treatment. The data that is published relates to the removal effectiveness of various air treatment processes, when applied, rather than to how widely such methods are used. The removal efficiencies which can be expected from various methods are shown in the following table.

Table V-30
Approximate Characteristics of Dust and Mist Collection Equipment (8)

Equipment type	Relative cost[a]	Smallest particle collected (μ)[b]	Pressure drop (inches H_2O)	Power used[c] $\left(\frac{\text{kw}}{1000\ \text{ft}^3/\text{min}}\right)$	Remarks
A. Settling chambers					
1. Simple	1	40	0.1–0.5	0.1	Large, low pressure drop, precleaner
2. Multiple tray	2–6	10	0.1–0.5	0.1	Difficult to clean, warpage problem
B. Inertial separators					
1. Baffle chamber	1	20	0.5–1.5	0.1–0.5	Power plants, rotary kilns, acid mists
2. Orifice impaction	1–3	2	1–3	0.2–0.6	Acid mists
3. Louver type	1–3	10	0.3–1	0.1–0.2	Fly ash, abrasion problem
4. Gas reversal	1	40	0.1–0.4	0.1	Precleaner
5. Rotating impeller	2–6	5	—	0.5–2	Compact
C. Cyclones					
1. Single	1–2	15	0.5–3	0.1–0.6	Simple, inexpensive, most widely used
2. Multiple	3–6	5	2–10	0.5–2	Abrasion and plugging problems
D. Filters					
1. Tubular	3–20	<0.1	2–6	0.5–1.5	High efficiency, temperature and humidity limits
2. Reverse jet	7–12	<0.1	2–6	0.7–1.5	More compact, constant flow
3. Envelope	3–20	<0.1	2–6	0.5–1.5	Limited capacity, constant flow possible
E. Electrical precipitators					
1. One-stage	6–30	<0.1	0.1–0.5	0.2–0.6	High efficiency, heavy duty, expensive
2. Two-stage	2–6	<0.1	0.1–0.3	0.2–0.4	Compact, air conditioning service
F. Scrubbers					
1. Spray tower	1–2	10	0.1–0.5	0.1–0.2	Common, low water use
2. Jet	4–10	2	—	2–10	Pressure gain, high velocity liquid jet
3. Venturi	4–12	1	10–15	2–10	High velocity gas stream
4. Cyclonic	3–10	5	2–8	0.6–2	Modified dry collector
5. Inertial	4–10	2	2–15	0.8–8	Abrasion problem
6. Packed	3–6	5	0.5–10	0.6–2	Channeling problem
7. Rotating impeller	4–12	2	—	2–10	Abrasion problem

[a] Including necessary auxiliaries. [b] With 90–95% efficiency by weight. [c] Includes pressure loss, water pumping, electrical energy.

Realistic evaluation of the treatments given to waste streams by industry, indicates that many hazardous materials are being released into the water streams and air streams. Fortunately, dilution reduces the hazards below the threshold levels of the human population, or the general pollution level is such that people refrain from exposing themselves to such air or water waste streams. The continuous increase in the amounts of wastes released and the variety of hazardous substances produced, indicates that the threshold safety levels may be exceeded in the future. Since the chronic effects of chemical substances are difficult to measure, the threshold levels of some substances may have been exceeded already.

The substances listed as hazardous compounds are examples of the types of toxic compounds which should be excluded from waste streams. If steps are taken to minimize their release, such actions will eliminate, concurrently, other compounds of comparable hazard.

6. DISPOSAL OF SMALL LOTS OF HAZARDOUS MATERIALS

The disposal of small amounts of hazardous materials is quite different from the treatment methods used to remove contaminants from water or air waste streams or from the disposal techniques which might be used to dispose of large amounts of a single compound. The objective when disposing of small amounts is to render the material harmless while ensuring the safety of the persons involved in the disposal and in the vicinity of the disposal action.

The disposal of relatively small amounts of hazardous materials poses unique problems. Such disposal problems arise in commercial operations which use a small amount of a variety of materials, or when such materials are used in retail establishments or households. The disposal means used most frequently are the conventional municipal services, trash collection and sewage systems. The disposal process normally consists of using the material fully and then discarding the container, or discarding the container with a small residue, or emptying the residual chemicals into a drain and then discarding the container. Problems arise when the containers are damaged or leak, or when the user is not familiar with safe handling and disposal practices.

Various techniques have been developed by the chemical industry to ensure safe disposal practices. When hazardous materials are in their pure form (e.g., as products), they are frequently transported and used in large quantities. On occasion, due to accidents, contamination, etc., it becomes necessary for the transporter or user to dispose of the otherwise valuable materials. The chemical industry has historically refrained from including disposal instructions on package labels, for two reasons. First, detailed disposal instructions would, in many cases, require inclusion of the product formulation, and such information is proprietary with the producers. The second, and very practical reason, is that the manufacturers have no way of knowing many of the ultimate users, particularly in terms of the users' technical knowledge and ability to understand fully any instructions that might be included on labels.

For these reasons, the chemical manufacturers have preferred to provide the service of taking back hazardous materials and disposing of the materials themselves. This is particularly true of the larger chemical manufacturing firms. Recently, however, the manufacturers have entered into a cooperative arrangement which provides a central point of contact for materials' users who encounter disposal problems, especially with respect to large spills. The central point is now the Manufacturing Chemists Association, and a common telephone number, termed the "hot line," is available to all users. This does not mean that the manufacturers no longer provide the disposal service, only that the necessary arrangements can be made through a single point of contact. Each occurrence is handled on its own characteristics, and the manufacturers feel that disposal instructions on labels will not become necessary. A series of publications have been prepared by various organizations as guides to the safe handling and disposal of hazardous compounds. Among these publications are:

- Industrial Data Sheets—National Safety Council. Information is provided on properties, uses, containers, shipping regulations, storage, hazards, handling, first aid, toxicity and waste disposal practices.

- Data Sheets and Chem-Cards—Manufacturing Chemists Association. Information is given on the properties, hazards, handling, storage, safety, waste disposal and first aid related to specific hazardous materials.

- Chemical Hazards Bulletins—American Insurance Association. Information given is similar to that in the previous publications.

- Hygiene Guide—American Industrial Hygiene Association. Information is provided on hygienic standards, toxic levels, and medical information on hazardous materials.

A large number of other publications provide data as to the safe handling of dangerous materials. A comprehensive list is contained in Chemical Safety References published by the National Safety Council.

The key reference to the safe disposal of hazardous materials is titled Laboratory Waste Disposal Manual published by the Manufacturing Chemists Association. This manual provides recommendations for the treatment and disposal of hazardous chemical wastes. The manual stresses safe procedures for onsite waste disposal from small laboratories, especially those in small communities not possessing sophisticated equipment. The compounds that are included in the list of hazardous compounds have been identified with a disposal method listed in this manual. This was accomplished by listing in the data records the disposal technique which is applicable. These disposal methods also assist in identifying the physical properties of the compound such as its flammability, explosive characteristics, and toxicity. Figure V-3 lists excerpts from the MCA Manual.

7. DISCUSSION AND CONCLUSIONS

Review of the data and information available on hazardous materials contained in industry waste streams indicates that sufficient data is not available to specifically identify and quantify the hazardous waste streams. While individual industrial production facilities may have detailed data, few have published such data. Where detailed studies of waste treatment processes have been made (the Deepwater Pilot Plan Treatability Study), the identification of waste streams to production facilities has been avoided. Historically, industry has not analyzed waste streams with the same level of interest and in the detail that is devoted to process output streams. The lack of data may also be due to a reluctance to identify materials that may create community-relation problems.

FIGURE V-3
Waste Disposal Procedure
Small Spills or Package Lots

Hazardous Wastes		Hazard Fire	Explosive	Neutralize	Dilute	Absorb	Dissolve in Solvent	Incinerate
1a	Organic Acid Halides			x	x			
1b	Inorganic Halides			x/xx	x			xx
2	Aldehydes	●				x	xx	x/xx
3	Alkali & Alkaline Earth Metals Alkyls & Alkoxides			x/xx	x			xx
4a	Chlorohydrins, Nitro Paraffins	●		x	x	xx		xx
4b	Organic Halogen & Related Compounds	●				x	xx	x/xx
4c	Substituted Organic Acids			x	x	xx	xx	xx
5	Aromatic Amines					x	xx	x/xx
6	Aromatic Halogenitor Amines & Nitric Compounds					x	xx	x/xx
7a	Aliphatic Amines			x	x		xx	xx
7b	Organic Phosphates					xx	x	x/xx
8	Azides & Axo Compounds		●	xx		x		x
9	Carbon Disulfide	●				x		x
10	Caustic Alkali & Ammonia			x	x			
11	'Inorganic Salts			x	x			
12a	Oxidizing Agents			x	x			
12b	Reducing Substances			x	x			
13	Mercaptans & Organic Sulfides	●		x	x		xx	xx

x Method one
xx Method two

FIGURE V-3
Continued

	Hazardous Wastes	Hazard Fire	Hazard Explosive	Neutralize	Dilute	Absorb	Dissolve in Solvent	Incinerate
14	Cyanides & Nitrates	●		xx	xx	x		x
15	Ethers	●	●				xx	x/ xx
16	Hydrazines	●		xx	xx	x		x
17	Hydrides	●		xx	xx	x		x
18	Hydrocarbons, Alcohols, Ketones, Esters	●				xx		x/xx
19	Inorganic Amides	●		x	x			
20	Organic Amides						x	x
21	Inter Non-Metallic Compounds	●		x	x			
22a	Inorganic Peroxides			x	x			
22b	Organic Peroxides	●				x		x
23	Inorganic Sulfides*	●				x		
24a	Organic Acids	●		x	x		xx	xx
24b	Inorganic Acids			x	x			
25	Carbides				x			x
26	Selected Gases Solids	Landfill or Air Release						
27a	Scrap Metals	Salvage						
27b	Mercury Recovery	Dissolve water soluble components - Convert others to soluble nitrates Precipitate mercuric sulfide - Dry - Ship to suppliers						
27c	Phosphorus	Cover with water - evaporate - burn						
27d	Arsenic, Antimony Bismuth			x	x			
27e	Selenium, Tellurium	Acidify, add sodium sulfite, heat, filter, dry & ship						
27f	Lead & Cadmium	Acidify with nitric acid, evaporate, dilute, add H_2S, filter, dry & ship						
27g	Beryllium	Acidify with HCL, filter, treat filtrate with NH_4OH, boil, precipitate, filter, dry & ship						
27h	Strontium-Barium							
27i	Vanadium	Add to lister of ammonium carbonate, add NH_4OH slowly, filter, dry and package						
27j	Halogenated Solvents	Distill or return to supplier						
28	Cellulose Nitrate	●	●					x

* Add $FeCl_3$

In view of these difficulties, assumptions must be made as to the probability of hazardous materials being present in conventional waste streams. Some information as to the type of materials in air, water and solid waste streams may provide an indication as to the control methods which may be needed and the type waste stream which must be considered for special disposal treatment.

In the absence of knowledge as to specific materials in the waste streams, the following reasoning can be used to establish the possibility of a signficant hazardous waste stream.

- It is essential to identify potentially hazardous disposal conditions. If hazardous materials are present in a waste stream, a hazardous waste condition may exist.
- The materials that are considered to contribute most to the creation of hazardous wastes are those that are the most toxic, corrosive, radioactive, explosive, flammable, etc., of those which are used or produced in commercial amounts.
- If hazardous materials are part of the raw material input or output stream (i.e., used or produced in the manufacturing facility), some fraction of the amount used will appear in the air, water or solid waste streams.
- The continuous use of a number of hazardous materials increases the probability that hazardous wastes are created.
- The use of deep-well disposal systems, disposal contractors, deep-sea disposal, or other special disposal methods may indicate the existence of hazardous waste streams.
- The presence of hazardous materials does not indicate that a hazardous condition exists. Many industrial processes involve hazardous materials that are controlled safely.
- When hazardous materials are distributed in small containers, such materials will appear in municipal waste streams.

- The presence of organic compounds in waste streams may indicate a hazardous waste. Little is known as to the chronic effects of most organic compounds. Relative hazardous effects are based largely on observed acute effects. Carcinogenic or similar chronic effects of many compounds are unknown.

The probability that a hazardous waste stream is produced at an industrial site can be estimated based on a set of material production-consumption characteristics. Table V-31, on the following page, indicates these characteristics and the evaluation of such characteristics for different segments of the industrial community.

Some industries produce waste streams that are typical of the industry, i.e., textile, pulp and paper, leather tanning, and plating wastes. The characteristics of these waste streams are similar. Other industries have highly variable waste streams. The chemical industry produces thousands of different materials by a wide variety of processes and may produce over a thousand different products at a single facility.

The quantities of wastes produced are dependent on the materials processed. The extractive industries produce large quantities of spoil from which the valuable ores have been extracted; for example, an average of seven barrels of brine is produced for each barrel of oil. Some industrial operations produce little waste; for example, the electrolysis of brine to produce chlorine and caustic, but such waste (mercury) may be significant although small in quantity.

The list of hazardous wastes that has been prepared identifies those substances which are significant wastes, even in relatively small amounts, because of their toxicity or other hazardous properties. It is not, of course, an exhaustive list of hazardous material, but does represent the type materials that create conditions which are potentially hazardous. This list provides a means to evaluate the potential hazards involved in a specific waste stream. If these compounds are present, it is presumptive evidence that a hazard exists which requires control.

The list can be used in several ways: to identify the producers of particularly hazardous materials, to identify the industrial consumers mers of such materials, and to identify the extent to which these materials enter the municipal waste streams.

Table V-31
Hazardous Material Use, Production and Wastes by Type Industry

Industry	Properties and Products Used					Properties Products Made					Toxic Materials Used					Toxic Materials Produced					Disposal Methods				Toxic Wastes Produced				
	C	E	F	R	P	C	E	F	R	P	S	H	G	O	I	S	H	G	O	I	DW	Sea	Con	AEC	S	H	G	O	I
10 Mining	x	x		x										x	x											x	x		x
20 Food			x							x				x															
22 Textiles	x		x		x						x	x		x												x		x	
26 Paper & Allied Products	x		x																			x					x		x
2812 Alkalis & Chlorine						x						x						x		x		x							x
2815 Cyclic Intermediates	x	x	x			x	x	x			x	x	x	x	x	x		x	x		x	x	x		x	x	x	x	x
2818 Organic Chemicals	x	x	x			x	x	x			x	x	x	x	x	x		x	x		x	x	x		x	x	x	x	x
2819 Inorganic Chemicals	x		x			x	x	x			x	x		x	x		x			x	x	x	x			x	x	x	x
282 Plastic Materials	x	x	x				x	x			x		x	x	x				x		x	x	x		x		x	x	
283 Drugs	x		x	x	x				x		x	x		x	x		x		x	x			x	x			x	x	x
284 Soaps & Cleaners	x		x			x					x			x	x				x									x	
285 Paints & Allied Products			x					x			x				x	x			x	x		x			x			x	x
287 Agricultural Chemicals	x	x	x				x	x			x	x		x	x			x	x	x	x	x	x		x			x	x
2892 Explosives	x						x	x			x			x	x				x	x			x					x	x
29 Petroleum & Coal Products	x	x	x				x	x			x	x	x	x	x	x		x	x	x	x	x	x		x	x	x	x	x
31 Leather Tanning	x		x								x	x		x	x											x		x	x
329 Asbestos Products															x					x							x		x
331 Blast Furnaces & Steel	x													x	x								x			x	x	x	x
333 Non Ferrous Metals	x													x	x					x							x		x
347 Metal Services	x		x								x	x		x									x		x	x			x
DOD	x	x	x	x			x	x	x		x	x		x	x			x			x	x		x	x	x	x	x	x
AEC	x			x					x					x	x						x		x			x	x	x	x
NASA	x	x	x				x	x			x		x	x							x		x		x		x	x	
Consumers	x	x	x	x	x						x	x		x	x								x		x	x		x	x

Hazard Code

C = Corrosive
E = Explosive
F = Flammable
R = Radioactive
P = Pathogenic

Toxic Code

S = Toxic solvents
H = Toxic metals
G = Toxic Gases
O = Toxic Organics
I = Toxic Inorganics

Disposal Code

DW = Deep well
SEA = Deep Sea Dump
CON = Contract Disposal
AEC = Radioactive Disposal

Constraints on interviews and the mailing of questionaires prevented a detailed analysis as to the specific locations that produce and use the materials on this list. A detailed analysis of a few major SMSAs should be made to identify the industrial use and commercial distribution of these materials. Such information should establish the practical relationships between these compounds and the hazard potential of air, water and solid waste streams. Then control measures based on these compounds, which insure their safe handling and disposal, will adequately protect against other compounds with similar properties.

The concept of controls over hazardous wastes must recognize the realities of waste production. Most wastes are created at the time a material is made or consumed. Most chemical compounds are produced and consumed within the chemical industry. Some are produced for retail use, while many compounds are used to a minor degree for small commercial, retail or household purposes. The major waste quantities are related to industrial production.

The industrial producers and consumers of hazardous materials operate extensive facilities which most frequently produce or consume a variety of chemicals. The waste treatment methods they use are designed to cope with a variety of materials to the degree needed to satisfy the legal requirements of local authorities. The waste treatment process is designed to produce wastes which are acceptable to the community. Such treatment facilities are not designed to completely remove hazardous effects. They reduce harmful effects to an acceptable level. Typically such treatment methods involve dilution of waste materials with water and the treatment of such wastes as part of a water stream.

Once introduced into water, compounds are not readily separated and the dilution factors insure that thousands and/or millions of gallons of water per day must be treated. The large quantities of water involved make it uneconomic to ship such waste streams. Local treatment is most practical. The shipment of conentrated waste streams are more economic than the shipment of dilute waste streams. Because of this truism, concentrated waste streams are more likely to be considered as candidates for movement to disposal sites other than those at the site where the waste originates.

Those waste streams which are now transported to offsite disposal plants or dumps provide an indication as to the type of waste streams which may be the initial candidates for national disposal sites. These collectable hazardous waste streams include:

- Ocean disposal of barge delivered liquid and solid wastes
- Deep-well injection streams
- Contract disposal wastes
- Munition disposal operations
- Radioactive wastes
- Industrial chemical containers.

The economics of waste disposal will determine, ultimately, the amounts and types of wastes that will be moved to distant disposal sites. It is unlikely that industry will move wastes if they can be treated satisfactorily and more economically at the point of origin.

The data in the table on the following page illustrates the type and quantities of materials now moved to offsite disposal locations.

Should deep-well disposal and deep-sea disposal be restricted, a substantial improvement in onsite capabilities for tertiary treatment will be required. Most wastes now deep-welled will require tertiary treatment to remove toxic contaminants.

Table V-32
Quantitative Data on Offsite Disposal Tonnages

Marine Disposal Operations - 1968(1)

Waste Type	Amount (tons per year)
Dredge Spoils	52,200,000
Industrial Wastes	4,690,500(2)
Sewage	4,477,000
Construction and Demolition	574,000
Explosive	15,200
Radioactive	4
Garbage	26,000
Miscellaneous	200
	61,982,904

Deep-Well Injection Streams - 1968(3)

Oil Field Brines	10,000,000 barrels/day
Chemical Wastes	>1,000,000 barrels/day
a. Inorganic Salt Solutions b. Mineral and Organic Acids c. Basic Solutions d. Chlorinated and Oxygenated Hydrocarbons e. Municipal Sewage	approximately 175 deep wells

Contract Disposal Wastes

30-40,000 tons annually

Munitions Disposal - 1970

80-120,000 tons Explosive Munitions
8,000 tons Chemical Munitions

Radioactive Wastes - 1963

70,000,000 gallons High Level Wastes Stored
7,000,000 cubic feet Solid Waste Buried at Atomic Energy Commission Sites
400,000,000 gallons Low Activity Waste Processed

Table V-32
(Continued)

Industrial Chemical Containers - 1971

193,000,000 Plastic Containers	75 percent $<$ 33 ounces 5 percent 33 to 127 ounces 20 percent $>$ 127 ounces

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(1) Ocean Disposal of Barge Delivered Liquid and Solid Wastes from U.S. Coastal Cities, Environmental Protection Agency, Report No. SW-19c, 1971.

(2) Industrial Wastes Include

Waste Acid	58 percent	2,720,000 tons
Refinery Wastes	12	562,000
Pesticide Wastes	7	328,000
Paper Mill Wastes	3	142,500
Other	20	938,000

(3) Injection Wells and Operations Today, E.C. Donaldson, U.S. Department of Interior, Bureau of Mines, Bartlesville, Oklahoma.

VI. MAJOR FINDINGS AND CONCLUSIONS

The following sections summarize the major findings and conclusions which were developed as the study progressed. They have been grouped under the following headings:

- Definition of Hazardous Wastes and Identification of Hazardous Effects
- Selection and Rating of Hazardous Materials
- Quantification and Distribution
- Waste Treatment Processes
- National Disposal Systems.

Many of the conclusions presented may overlap these categories and relate to two or more general areas, but this is only indicative of the complex, integral nature of the hazardous waste and hazardous effects problem.

1. DEFINITION OF A HAZARDOUS MATERIAL AND HAZARDOUS EFFECTS

It is difficult to give a simple explanation of what is meant by the term hazardous. The term implies a substance, or mixture of substances, which has (have) an inherent potential of being harmful to man or to the environment. In this context, the term also tends to describe a condition or situation rather than a material. The situation could involve a toxic substance, a flammable or explosive substance, or a highly reactive substance. A reactive substance, in turn, could cause fire, explosion, or the formation of toxic substances. All substances in these latter categories, as well as others not specifically mentioned here, have a potential to produce harmful effects to humans, plants, animals, etc. They could, therefore, by classed as hazardous substances. The term "potential" is significant, since a great many materials are suspected of being hazardous to various life forms, but too little is known factually about their hazardous effects to permit including them in the hazardous category. It is the effort to hold to facts that has resulted in the relatively short list of materials identified as hazardous in this study.

The term hazardous also connotes an element of change or uncertainty. In the context of waste materials and their potential dangers, chance or uncertainty derive from the various ways that humans or the environment can be exposed to harmful amounts of a waste substance. Harmful amounts vary and are dependent upon factors such as the type of receptor (i.e., humans, plants, animals, etc.), the type and amount of exposure (i.e., levels of concentration, magnitude of dose necessary for damage to occur, magnitude of explosion, violence of reaction, etc.), and the duration of exposure.

To appraise one hazardous substance relative to another, comparison must be made on the basis of criteria which serve as standards for rating each appropriate factor, as described above.

When the nature of hazardous wastes is thus understood, the difficulty of defining and listing hazardous wastes becomes more apparent. The process of creating the toxic materials and the methods used to treat such materials when they become waste can be better described. Evidence as to the deleterious effects of such materials is more elusive.

The following conclusions have been reached concerning the definition of hazardous materials and hazardous effects:

(1) Knowledge of the long-range effects of chemical components is quite limited. Severe knowledge gaps, concerning both ecological systems interrelationships and the total effects of hazardous substances on all receptors, limit understanding as to which factors are pertinent and most important to the identification of hazardous compounds.

(2) By using an extensive set of criteria to define hazardous substances, a list of substances which possess a high potential for creating hazardous conditions as uncontrolled wastes can be developed. This list is valuable for defining the relative dangers which may develop if hazardous substances are not controlled throughout their life cycle.

(3) The development of a list of hazardous substances is not equivalent to the development of a list of hazardous wastes, largely because of the unknown nature of effects possible from mixed waste streams, especially synergistic effects of a variety of input materials.

(4) Wastes to be hazardous must contain one or more hazardous substances in sufficient concentration to be detrimental to human health or other elements of the ecological system.

2. SELECTION AND RATING OF HAZARDOUS MATERIALS

As part of the current study, a list of "hazardous compounds" was developed and each compound was later rated, relative to the others listed, on the basis of a defined set of criteria. Knowledge gaps have a critical impact on the list of hazardous substances. In particular, knowledge of the long-range effects of chemical compounds on man or the environment are quite limited. In many instances it may take years for the effects of new compounds, or even compounds now in use, to be noticed and be traced directly to a particular chemical compound. Quantitative cause and effect relationships will take additional time to establish. Because of this, it is likely that many compounds or materials with highly deleterious long-range effects are not on the list developed during this study.

Conclusions reached relative to the selection and rating of hazardous materials include:

(1) The list of 424 hazardous compounds which has been developed is representative of a larger unidentified set or list of hazardous compounds.

(2) The list of hazardous compounds can be useful for future research in tracing the flow of identified hazardous compounds from their points of manufacture to points of use, and to categorize their status at any given time as:

- Intermediate in manufacturing processes
- Consumables in manufacturing processes

- Hazardous end products
- Nonhazardous end products
- Others.

(3) Knowledge concerning the presence of particularly toxic compounds in complex waste streams provides useful indication of the amount of waste control or treatment required.

(4) Continual industrial process and product changes produce a continuous stream of new compounds, some of which are hazardous. Data deficiencies relative to this stream introduce the possibility of omissions of some hazardous materials from the list. However, the development of a meaningful program to deal with hazardous wastes is not dependent upon a complete or totally comprehensive list and rating of hazardous substances.

(5) The rating procedure developed includes ratings on the basis of known effects to ecological populations and the effects of flame, explosion, and reaction in addition to human toxic effects. Also, the rating system is modular in design providing a flexible capability to:

- Develop and examine alternative ratings on the basis of adjusted weightings of the various modules
- Develop specific hazard ratings for human effects, other ecological effects, or flame/explosion/reaction effects either individually or by any combination
- Develop specific hazard ratings for air, water, or land disposal either individually or by any combination.

3. QUANTIFICATION AND DISTRIBUTION

Initial waste streams of production plants include process, storage, and package product wastes. Each customer also develops wastes either as process waste streams or as packaged wastes. Estimates of probable waste quantities are frequently made based on fractions of the total production. Such estimates provide a general indication as to disposal needs.

Several conclusions have been reached with respect to quantification and distribution of hazardous materials:

(1) Gross quantification data (i.e., number of pounds of waste material produced in different areas by type industry), is useful as a general indicator of the magnitude and pervasiveness of industrial waste streams. Such data assists in defining the scope of the problem and gives some indication as to disposal needs.

(2) While gross quantification data are useful and valid, as described above, their use to estimate the quantities of wastes in a particular geographical area with an implied degree of accuracy is probably not valid and may lead to erroneous conclusions, because of the great number of variables in production processes within small segments of any one industry.

(3) The amount of waste produced does not indicate the hazards which may be produced by such wastes. Hazardous wastes must produce toxic concentration effects greater than can be tolerated by the threatened life system. The existence of such concentrations must be established on a continuing plant-by-plant basis by analysis of waste generated.

4. WASTE TREATMENT PROCESSES

Any waste stream may be hazardous under certain conditions. That is, the toxicity of the materials, the susceptibility of the environment, and the concentration in the air, soil, or water may exceed the tolerable levels.

The disposal treatment required and the facilities needed to cope with hazardous wastes are specifically related to the products made, the processes involved, waste stream characteristics, and local geographic, demographic, and environmental conditions. Each industrial facility will find it necessary to tailor disposal facilities to its individual needs, i.e., methods cannot apply in common even across single industries.

In general, disposal processes at individual plants treat only the waste streams originating in the production process. That is, they do not contribute materially in disposing of packaged products which frequently create additional hazardous disposal conditions. Municipal disposal systems, for example, are not designed to deal with potentially hazardous materials. In general, dilution with other materials is the only operational safeguard currently in use.

Means to control the hazards associated with the disposal of toxic explosive materials used in business and households need to be developed. The studies which have been made for pesticides indicate some of the actions which are needed. Current regulations covering drugs and other carefully controlled products such as rodenticides and alcohol may provide insights into the means to control the movement and disposal of such materials.

The following specific conclusions were reached in the above study areas:

(1) Accurate characterization of waste streams is essential to the evaluation of hazard potentials and to the design of waste treatment to abate such hazards, yet these characterizations have not been made in the majority of industrial situations.

(2) Waste characterization data should be used to identify the specific treatments which are required and the removal or corrective efficiencies which must be achieved once criteria for waste is established. The most useful approach appears to be the development of disposal processes which can be used to dispose of a wide variety of compounds by a single treatment sequence.

(3) Following conclusion 2 above, indepth studies of specific industrial processes are needed in several areas in order to:

- Determine the composition of associated waste streams in detail
- Establish the feasibility of separating certain hazardous compounds from general waste streams (e. g., heavy metals, phenols)
- Develop alternative ways of categorizing and rating treatment requirements of composite waste streams.

(4) The selection of waste treatment systems and disposal sites is highly influenced by external conditions such as data concerning geology, topography, meteorology, population density, industry concentrations, and political boundaries. Indepth studies into these external conditions are needed to avoid costly long-term miscalculations.

(5) Data on waste characteristics for individual plants obtained by the Corps of Engineers, through enforcement of the Refuse Act of 1899, should be used for conversion into estimates of disposal treatment needs and costs by means of relatively simple automated calculations. Such estimates can be accumulated into data specific to plants, localities, and regions and be the basis for national disposal planning and control.

5. NATIONAL DISPOSAL SYSTEM

While it is intuitively acceptable to expand the operational practices of the AEC for radioactive wastes to other materials which tend to create hazardous conditions, these practices may not be applicable to the wide range of industrial wastes. Radioactive wastes by and large are inevitable by-products of other operations. With few exceptions little use has been found for them. On the other hand, most hazard creating chemical compounds are produced for specific purposes and needs. The wastes involved in their production process may or may not create conditions which are hazardous. Generally speaking, the chemical industry has dealt successfully with toxic/flammable/explosive compounds and possess the technology to dispose of all waste safely.

Specific conclusions with respect to the development of a national disposal system or systems are:

(1) A national disposal system can minimize toxic wastes by:

- Improving plant treatment practices
- Improving controls over materials in distribution channels
- Defining subsystems for collecting specific toxic residues
- Developing improved packages which will assist in the safety and completeness of disposition.

(2) National disposal sites should be developed only if needed as part of a comprehensive hazardous material system.

VII. RECOMMENDATIONS

1. HAZARDOUS WASTE CONTROL SYSTEM

Develop a national hazardous waste control, collection and disposal system which might include as a component, as needed, hazardous waste disposal sites and processes. The system concept should consider all steps necessary to control designated hazardous substances from their initial production through intermediate stages of use to final disposal.

Control system development should incorporate the following major tasks:

- Identification of critical waste processes or products
- Licensing of production and disposal processes
- Specification of handling and treatment methods
- Inspection for conformance
- Prescriptions for labeling, warnings and disposal methods
- Designation of collection points for specific waste categories requiring special handling
- Licensing of contractors for disposal or recycling
- Designation of ultimate disposal methods
- Development of implementation plan.

2. INDEPTH HAZARDOUS MATERIAL STUDY

Conduct an indepth study of a limited number of hazardous materials in order to establish the quantities, distribution and disposal possibilities. In essence this study would serve as a feasibility study for a national hazardous waste control system. Tasks would include:

- Selection of about 10 to 15 hazardous materials based on highest production quantities and widest distribution
- Investigation of production, distribution, and disposal patterns for selected materials
- Determine possibilities and problems with a national disposal system
- Preparation of a national profile to illustrate the findings
- Develop projections for a national system for a large number of hazardous wastes.

3. WASTE STREAM HAZARD ANALYSIS

Conduct a study of plant waste streams to establish waste characteristic profiles, identify the hazardous parameters of a given waste content and recommend treatment profiles. Treatment processes will be directed toward the processing required to achieve the minimum acceptable standard for introduction to a municipal treatment system. Major tasks would include:

- Identification of municipal acceptance standards
- Collection of typical waste characteristic profiles from Corps of Engineers
- Identification of treatment level (by characteristic) for various wastes which is necessary to meet standard
- Establishment of automated program to read-in waste profile and read-out treatment profile

- Provide routine to
    - Estimate cost of adequate treatment facilities by type and quantity of waste
    - Estimate sludge and other residue production in industrial and municipal treatment
    - Sort data—profile, treatment requirements, costs, effluent quantity, SIC, geographical location
- Preparation of computer program for above
- Provide for analysis of inplant processes by these methods.

4. HAZARDOUS EFFECTS RESEARCH

Launch a research effort directed toward the specific task of identifying the hazardous effects of various materials. The result of this effort should be combined with a program to require firms to file data on new compounds (similar to FDA Requirements). Criteria for such industry data should also be established. Major tasks in this effort would include:

- Analysis of new chemical substances and other potentially harmful substances
- Early identification and characterization of substances which may produce hazardous effects due to long-term persistence and toxic effects of accumulation
- Determination of persistency of toxic substances in soil, water, etc.
- Determination of mutagenic and carcinogenic effects.

A specific laboratory should be tasked to monitor and direct this research program and to assemble, correlate, and distribute data acquired through this research effort.

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INTRODUCTION

The fundamental effort in conduct of the Hazardous Materials Study was a literature survey. The principal objective of this analytical survey was a systematic screening of available literature data. Several thousand abstracts were obtained, perused by the study team, and assessed according to their relevance within the context of the study. Requests were then submitted for those documents felt to be most propitious. Additional documents were identified and acquired as a result of personal interviews conducted with representatives of industry, trade associations, and Governmental agencies. In all, approximately 800 documents were accepted as containing information worthwhile to the purposes of the study.

In accordance with the major thrust of this study and the contents of the acceptable documents, three separate categories were established for cataloging the incoming material. These major categories are:

- Standard Industrial Classification (SIC) Codes
- Disposal Practices and Techniques, and Types of Pollution
- Supplementary Reference Material.

Within each category, further subjective differentiation was made, and is reflected in the table of contents to this bibliography as an aid to the user in locating references of interest among the very large number included.

Consequently, as each document was received, the required bibliographical information was recorded, a control number was given, and the document was filed by subject within the appropriate category. The bibliographical information was also filed categorically for easy reference and for later transcription. Distinction was made between articles, magazines, reports, and books. All literature was identified by title, since this seemed to be most conducive for easy access of the documents. Both the study team and EPA personnel referred to material by title, and, in most cases, the title implied the subject content of the document. In addition, the company, association, Governmental agency, etc., with which the author was associated at the time of publication, proved to be beneficial in analyzing the literature data, and this information was included in the bibliographical material.

This bibliography contains all information discussed above for those documents considered to be acceptable. This information is separated into the three categories and a brief description of each category precedes the literature listing.

1. STANDARD INDUSTRIAL CLASSIFICATION (SIC) CODES

Thirteen major SIC codes were selected in this category. The last two sections are not SIC codes but represent major agencies, within the government, that must be considered in a study of this nature: the Atomic Energy Commission and the Department of Defense. Several major SIC codes are further classified by the finer SIC code breakdown. Within each section, all documents are listed alphabetically by title according to the type of material: article, magazine, report, and book.

SIC 01 - AGRICULTURAL PRODUCTION

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SIC 22 - TEXTILE MILL PRODUCTS

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